

Managing Physical Hazards

Lecture Title:

Noise & Vibration Hazards Exposure, Measurement & Control

Lecturer: Chris Camilleri

Date: 16th March 2025



**Undergraduate Diploma in
Occupational Health and Safety**

Welcome and Objectives

A combined deep-dive into noise and vibration as key occupational hazards.

Covers sound physics, vibration transmission, exposure metrics (LEX,8h & A(8)), health effects (Noise Induced Hearing Loss, Hand-Arm Vibration Syndrome and Whole Body Vibration), Subsidiary legislation, measurement techniques, audiometry, and engineering/administrative control strategies for both hazards.



Welcome, Module Roadmap & Transition from Risk Management

Lecture 1 — Introduction to Physical Hazards & Regulatory Frameworks

Lecture 2 — Measurement & Monitoring Techniques for Physical Hazards

Lecture 3 — Noise & Vibration Hazards: Exposure, Measurement & Control

Lecture 4 — Physical Hazard Control Strategies: Engineering, Administrative & PPE

Lecture 5 — Thermal Hazards: Heat Stress, Cold Stress, and Thermal Comfort

Lecture 6 — Radiation Hazards: Ionising and Non-Ionising

Lecture 7 — Lighting, Visibility, and Workplace Ergonomics

Lecture 8 — Machinery, Mechanical Hazards & Machine Safeguarding

Lecture 9 — Workplace Environment Hazards: Slips, Trips, Falls, and Confined Spaces

Lecture 10 — Integrated Physical Hazard Management & Continuous Improvement

This module focuses on physical agents and their technical, physiological, and legal considerations



What does the law say?

Employer commitment to preventing work related injury/illness in the workplace.

Responsibilities

- ▶ Employer: to maintain a safe and healthy work place
- ▶ Employee: to work safely following safe work practices
- ▶ Supervisor: to ensure that safe and healthy work conditions are maintained in assigned work area.



(Subsidiary Legislation S.L. 646.20) Work Place (Minimum Health and Safety Requirements for the Protection of Workers from Risks resulting from Exposure to Noise) Regulations



(Subsidiary Legislation S.L. 646.20)

The regulations stipulate the following values.

1. Lower exposure action value: 80dB(A), peak pressure of 135 dB(C)
 2. Upper exposure action value: 85dB(A), peak pressure of 137 dB(C)
 3. Exposure limit value: 87dB (A), peak pressure of 140 dB(C)
- *where noise exposure exceeds the lower exposure action values, the employer shall make individual hearing protectors **available** to workers*
 - *where noise exposure matches or exceeds the upper exposure action values, individual hearing protectors shall be used*

(Subsidiary Legislation S.L. 646.20)

The assessment and measurement referred to in subregulation (1) shall be planned and carried out by competent persons at suitable intervals.

The results obtained from the assessment and, or measurement of the level of exposure to noise shall be preserved in a suitable form so as to permit consultation at a later stage.

(Subsidiary Legislation S.L. 646.20)

The risk assessment shall be recorded on a suitable medium.

The risk assessment shall be kept up to date on a regular basis, particularly if there have been significant changes which could render it out of date, or when the results of health surveillance show it to be necessary.

(Subsidiary Legislation S.L. 646.20)

(2) On the basis of the risk assessment referred to in regulation 4, if the upper exposure action values are exceeded, the employer shall establish and implement a programme of technical and, or organisational measures intended to reduce the exposure to noise, taking into account in particular the measures referred to in sub-regulation (1).

(3) On the basis of the risk assessment referred to in regulation 4, work places where workers are likely to be exposed to noise exceeding the upper exposure action values shall be marked with appropriate signs. The areas in question shall also be delimited and access to them restricted where this is technically feasible and the risk of exposure so justifies



(Subsidiary Legislation S.L. 646.20)

Minimum Requirements for the Use of Personal Protective Equipment at work Regulations, and under the conditions set out below:

- (a) where noise exposure exceeds the lower exposure action values, the employer shall make individual hearing protectors available to workers;
- (b) where noise exposure matches or exceeds the upper exposure action values, individual hearing protectors shall be used;
- (c) the individual hearing protectors shall be so **selected** as to eliminate the risk to hearing or to reduce the risk to a minimum.

(Subsidiary Legislation S.L. 646.20)

1)**training** relating to risks resulting from exposure to noise concerning, in particular:

(a) the **nature of such risks**;

(b) **the measures** taken to implement these regulations in order to eliminate or reduce to a minimum the risks from noise, including the circumstances in which the measures apply;

(c) **the exposure limit values** and the exposure action values,

(d) the results of the risk assessment and explanation of their significance and potential risk;

(e) **the correct use of hearing protectors**;

(f) why and how to detect and report signs of hearing damage;

(g) the circumstances in which workers are entitled to health surveillance and the purpose of such **health surveillance**,



(Subsidiary Legislation S.L. 646.20)

A worker whose exposure **exceeds the upper exposure action values** shall **have the right to have the hearing checked by a doctor.**

Preventive audiometric testing shall also be available for workers whose exposure exceeds the lower exposure action values, where the assessment and measurement provided for in regulation 4 indicate a risk to health.

Health records shall contain a summary of the **results of the health surveillance carried out**, and shall be kept in a suitable form so as to permit any consultation in a confidential manner at a later date.

Where, as a **result of surveillance** of the hearing function, a worker is found to have an **identifiable hearing damage**, a doctor or a specialist if the doctor considers it necessary, **shall assess whether the damage is likely to be the result of exposure to noise at work**

Summary

Subsidiary Legislation S.L. 646.20

1. Determination and assessment of risk
2. Reduction of risks resulting from exposure to noise
3. Information and training for workers
4. Consultation and participation of workers
5. Health Surveillance

(Subsidiary Legislation S.L. 646.21) Work Place (Minimum Health and Safety Requirements for the Protection of Workers from Risks resulting from Exposure to Vibrations) Regulations



(Subsidiary Legislation S.L. 646.21)

1) The exposure limit value and action limit value for **hand-arm vibration** shall be as follows:

(a) the **daily exposure limit value** standardised to an eight-hour reference period shall be 5 m/s²;

(b) the **daily exposure action value** standardised to an eight-hour reference period shall be 2.5 m/s².

2. The exposure limit value and action limit value for **whole-body vibration** shall be as follows:

(a) the **daily exposure limit value** standardised to an eight-hour reference period shall be 1.15 m/s²;

(b) the **daily exposure action value** standardised to an eight-hour reference period shall be 0.5 m/s².

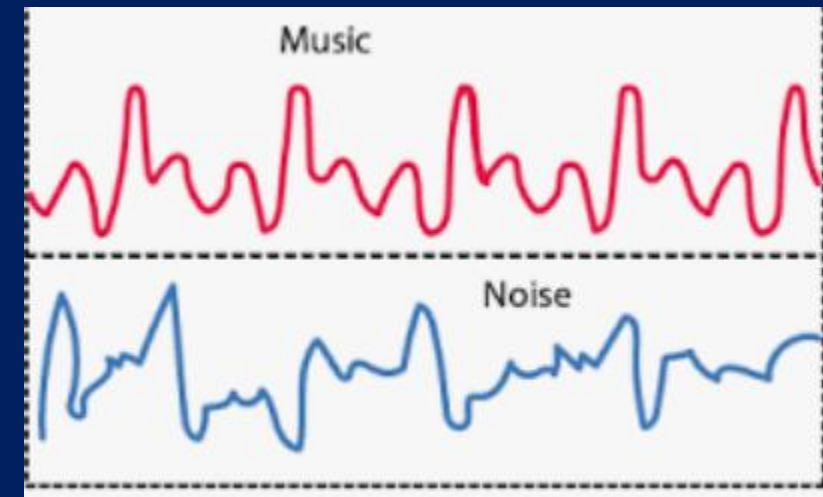


Noise & Vibration

Is a Physical Agent

Are sources of energy that may cause injury or disease. This means that it has physical energy resulting from the vibration of an object and the subsequent movement of air molecules.

Noise is also ambient



What is noise?

1. Unwanted Sound
2. Measured in decibels (dB)
3. Frequency: Sound waves are movements of air molecules that our ears translate into sound, and frequency refers to the number of cycles these waves complete in a second. This measurement of cycles per second is expressed in Hertz (Hz), with a higher Hz representing higher frequency sound



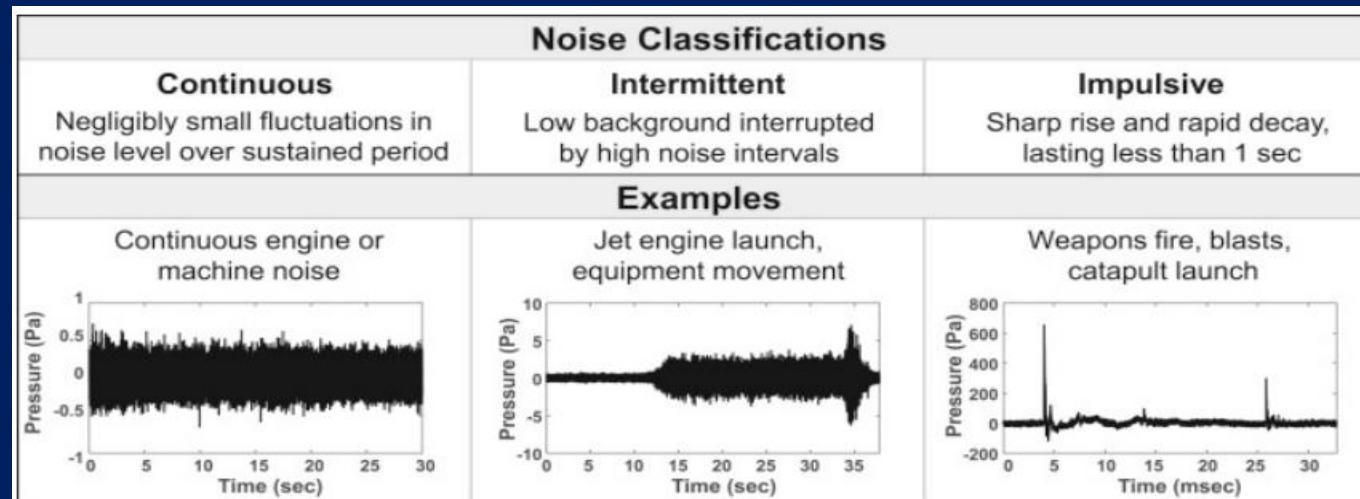
How is Noise measured?

1. Noise is measured in decibels (dB).
2. The decibel scale is logarithmic, which means that loudness is not directly proportional to sound intensity. Instead, the intensity of a sound grows very fast.
3. dB(A) – A weighting – to measure average noise.
4. dB (C) - C weighting – to measure peak, impulsive or explosives
5. You might just notice a 3 dB change in noise level, because of the way our ears work



Types of noise

- **Continuous:** noise heard constantly throughout the shift
- **Intermittent:** noise heard off and on throughout the shift
- **Impulse/Impact:** a sudden loud burst of noise of very short duration



What is Sound Pressure Level (SPL)

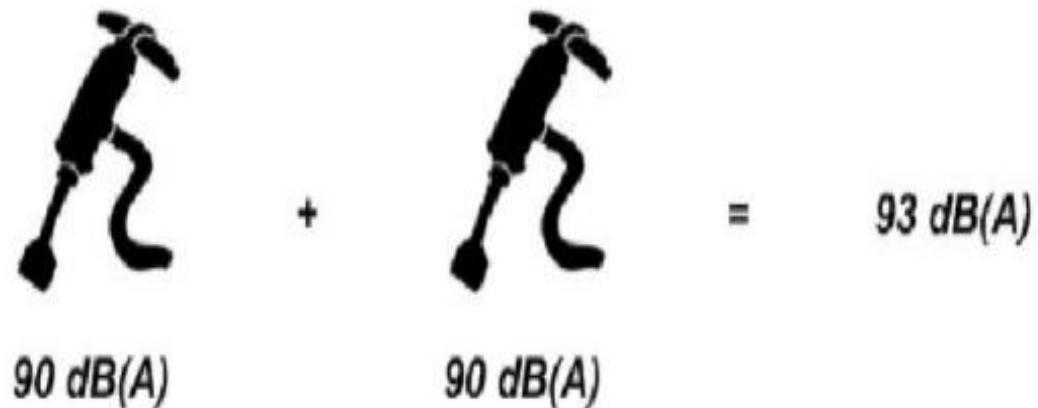
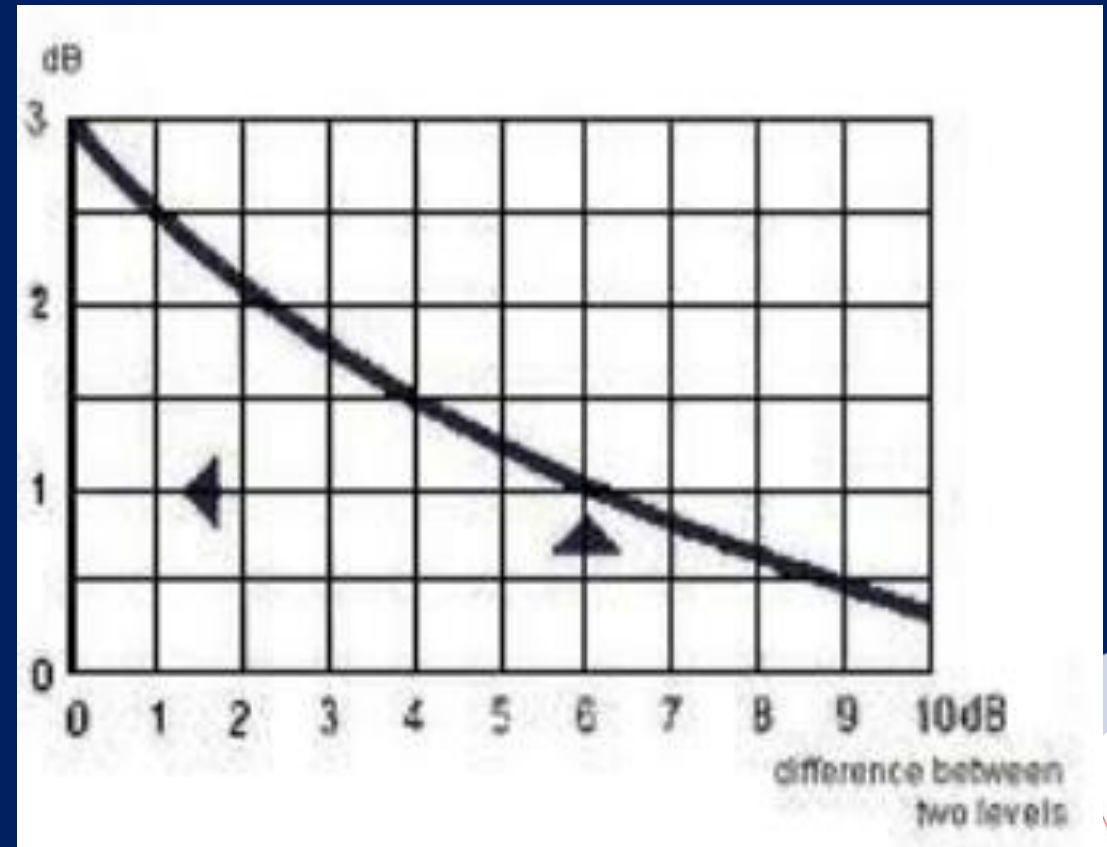
The sound level (on a basic level – how loud something is) can be perceived differently by different people so we need to have a means to get an objective measurement of sound level expressed in numerical terms.

This is defined as Sound Pressure Level (SPL)



Addition of SPL

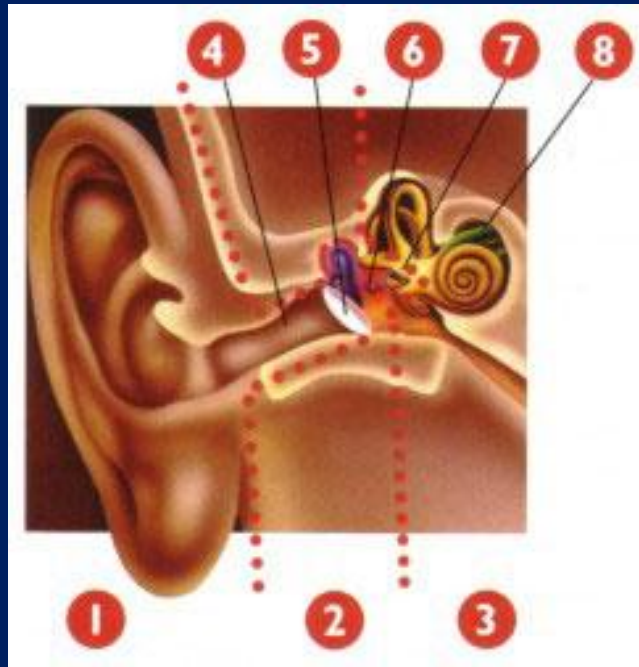
Doubling of the Pressure increases noise levels by 3dB



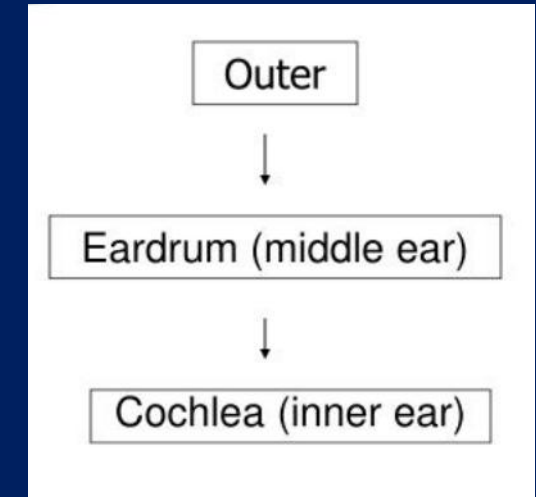
Decibel levels (SPL: Sound Pressure Levels)

0	Faintest sound heard by human ear
30	Whisper, quiet library
60	Normal conversation, sewing machine
90	Lawnmower, shop tools, truck traffic
100	Chainsaw, pneumatic drill
115	Sandblasting, loud rock concert, auto horn
140	Gun muzzle blast, jet engine

Anatomy of the ear



1. Outer Ear
2. Middle Ear
3. Inner Ear
4. Ear Canal
5. Eardrum
6. Ossicles
7. Oval Window
8. Auditory Nerve



Noise does not damage the ear randomly it affects specific structures:

1. The outer ear funnels sound.
2. The middle ear amplifies vibrations.
3. The inner ear (cochlea) converts vibration into nerve signals

What harm does noise do....

1. Hearing loss
2. Tinnitus
3. Safety
4. Fatigue / Low productivity
5. Communication problem
6. Annoyance and stress



Noise assessment

1. Identify hazards – noise and its source
2. Assess the risk that may result because of the hazard
3. Decide on control measures to prevent or minimize risk
4. Implement the control measures
5. Monitor and review the effectiveness of the measures



Assess

1. The first step in assessing noise exposure in the workplace is to **conduct a noise survey.**
2. Things to consider:
 - Purpose of measurement
(compliance with noise regulations, hearing loss prevention)
 - Noise patterns (where they occur in the workplace, and how often)
 - Location of people who are exposed to the hazard.



Control

3. At the source:

- Engineering controls
 - Designing quieter machines
 - Modifying existing equipment
- 4. Isolating vibrating parts within a machine
- 5. Add sound-absorbing materials or mufflers
- 6. Vibration padding



Control

6. Along the path:
 - Redesign floor plan of work area
 - Keep rest areas, lunch rooms etc from noise source
 - Separate worker from noise source
7. Erect sound barriers
8. Use sound-absorptive materials
 - Acoustic tiles



Control

9. At the worker

- Job rotation
- Conduct noisy operations during non-working hours
- Personal Protective equipment
 - Earplugs, earmuffs



Challenges

1. Control at the source is generally the most expensive
 - Involves heavy capital investment in new equipment and machinery redesign
2. Management must convince executives that this is a necessary expense using a cost-benefit analysis
 - Noise-based illness, absenteeism, worker's compensation costs
3. Required workplace training on noise hazards
4. Evaluate effectiveness of programs
 - Monitor noise hazards in the workplace
 - Record-keeping and scheduling of noise and hearing tests
 - Maintain records, claims, and injury report.



Types of protective equipment



Care and maintenance of PPE

1. PPE are regularly cleaned.
2. Do not share with others.
3. Inspect and maintain them.
4. Replace if worn out.
5. Select adequate type to reduce noise level required.
6. Use them effectively, do not be reluctant.



Why we use hearing protection?

1. Convenience and availability
2. Belief that the device can be worn correctly
3. Belief that the device will prevent hearing loss
4. Belief that the device will not impair a workers ability to hear important sounds
5. Comfort
6. Adequate noise reduction
7. Ease of fit
8. Compatibility with other personal protective equipment



Criteria that should be used when selecting hearing protection ?

There are 5 essential requirements for selecting the correct personal hearing protector:

1. CE marking,
2. Suitable Sound Attenuation (SNR)
3. Comfort
4. Adapted to the work environment and the nature of work &
5. Awareness of possible medical problems

Purpose of Noise Measurement

Why Measure Occupational Noise?

Key points:

1. Quantify daily exposure (LEX,8h)
2. Identify tasks contributing the most noise
3. Determine if exposure exceeds:
 - Lower action values
 - Upper action values
 - Exposure limit values
4. Provide data for risk assessment
5. Guide hearing protection selection
6. Comply with legal and ISO standards



Types of Noise Measurement Instruments

1. Sound Level Meter (SLM)

- Hand-held
- Used for spot measurements

2. Noise Dosimeter

- Worn on the worker
- Measures full-shift exposure
- Ideal for variable or mobile tasks

3. Octave-band Analyzer

- Breaks noise into frequencies
- Typically used when selecting controls

Types of Noise Measurement Instruments



Sound Level Meter



Dosimeter

ISO 9612 — Noise Exposure Measurement

Determination of occupational noise exposure

Purpose

Provides a standardised method for determining a worker's daily noise exposure ($L_{EX,8h}$).

Main Features

1. Sets requirements for: a) **Measurement equipment** (SLMs, dosimeters, calibration) b) **Task-based sampling strategy** c) **Data quality and measurement uncertainty**
2. Uses work-task-based assessments: a) Identify tasks b) Measure representative samples c) Calculate exposure contributions
3. Defines methods for: a) Full-shift dosimetry b) Task-based measurements c) Job-based measurements

ISO 9612 — Noise Exposure Measurement

Determination of occupational noise exposure

ISO 9612 is a methodology standard, meaning:

1. It tells you how to perform an occupational noise exposure assessment.
2. It tells you how to collect representative data.
3. It tells you how to calculate $L_{EX,8h}$ from measurement data.
4. It ensures that exposure results are repeatable, defensible, and compliant.



ISO 9612 — Noise Exposure Measurement

Determination of occupational noise exposure.

How?

1. Define the Scope and Objectives

ISO 9612 specifies that a noise exposure assessment begins by defining the goal, the worker group, and the type of work being assessed.

This includes determining whether the assessment is for compliance, epidemiology, or prioritising control measures.



ISO 9612 — Noise Exposure Measurement

Determination of occupational noise exposure.

How?

2. Conduct a Work Analysis (Critical Step)

ISO 9612 requires a structured work analysis before measuring.

- I. Identifying all relevant tasks or work activities
- II. Estimating the duration of each activity
- III. Estimating which tasks contribute to noise exposure.



ISO 9612 — Noise Exposure Measurement

Determination of occupational noise exposure.

3. Select the Appropriate Measurement Strategy

ISO 9612 defines three strategies for measuring noise exposure:

- I. **Task-based:** Measure representative noise levels for each task, then combine exposure based on task duration. Preferred when tasks can be clearly identified.
- II. **Job-based:** Random sampling without analysing the tasks; used when task analysis is not possible.
- III. **Full-day measurement:** Noise dosimeter worn throughout the full shift.

ISO 9612 states all three are valid but task-based is preferred as it provides most information for risk management



ISO 9612 — Noise Exposure Measurement

Determination of occupational noise exposure.

4. Use Compliant Instrumentation

ISO 9612 specifies the instrumentation requirements

(class 1 meters, calibrated devices, personal sound exposure meters),
including verification procedures before and after measurements.



ISO 9612 — Noise Exposure Measurement

Determination of occupational noise exposure.

5. Collect Representative Measurements

ISO 9612 requires:

- I. Repeated measurements for each task
- II. Sampling across different workers
- III. Ensuring measurements reflect typical working conditions

This ensures statistical reliability and reduces uncertainty.



ISO 9612 — Noise Exposure Measurement

Determination of occupational noise exposure.

6. Calculate Daily Noise Exposure (LEX,8h)

The standard defines how to:

- i. Combine task measurements and durations
- ii. Compute the 8-hour normalised exposure
- iii. Consider A-weighted levels (and optionally C-weighted)

7. Estimate Measurement Uncertainty

ISO 9612 uniquely requires an uncertainty estimate, so results are defensible and reliable.

ISO 9612 — Noise Exposure Measurement

Determination of occupational noise exposure.

8. Report Results in a Standardised Format

- The final report must include:
- Method used
- Instrumentation
- Work analysis
- Measurement data
- Calculated LEX,8h
- Uncertainty

This standardisation supports regulatory compliance and risk management decisions.



Summary

1. Is there a noise problem?
2. Noise assessment
3. Tackle noise at source
4. Determine best way to reduce or control noise
5. Implement control measures
6. PPE as a last resort
7. Get a competent person in the field!



Vibration Hazards

1. Vibration hazards are closely associated with noise hazards because tools that produce vibration typically also produce excessive levels of noise.
2. Vibration-related problems are serious widespread.
3. Up to 8 million workers are exposed to some type of vibration hazard, and of these, it is estimated that more than half will show some signs of injury.
4. Types of injuries associated with vibration depend on its source.



Vibration Hazards

5. The most common vibration related problem is known as **hand-arm vibration (HAV)**.
6. HAV is a form of **Reynauds Syndrome**, striking workers who use vibrating power tools daily as part of their jobs.
7. Working with vibrating tools in a cold environment is more dangerous than the same work in a warm environment.



Vibration hazards

1. Prevention is especially important with HAV because the disease is thought to be irreversible.
2. Treatments developed to date only reduce the symptoms.
3. Prevention strategies that can be used in any company regardless of its size
4. Purchase low-vibration tools.
5. Limit employee exposure.
6. Change employee work habits



WB Vibration

1. WBV refers to mechanical energy oscillations which are transferred to the body as a whole (in contrast to specific body regions), usually through a supporting system such a seat or platform.
2. Typical exposure include driving automobiles and trucks and operating industrial vehicles.

Health Effects of Whole-Body Vibration (WBV)

1. Musculoskeletal Disorders

- Lower back pain (most common)
- Degeneration of spinal discs
- Lumbar spine injury and chronic spinal disorders
- Increased risk of herniated discs

2. Digestive System Effects

- Stomach discomfort, indigestion
- Reduced gastrointestinal motility with ongoing vibration exposure

Health Effects of Whole-Body Vibration (WBV)

3. Circulatory and Cardiovascular Strain

- Disruption of blood flow
- Increased fatigue

4. Balance and Vision Effects

- Temporary balance disturbances
- Difficulty focusing on screens

5. Fatigue & Performance Issues

Reduced alertness

- Higher risk of driving or operational errors

Health Effects of Hand-Arm Vibration (HAV / HAVS)

1. Neurological (Nerve Damage)

- Tingling, pins & needles
- Numbness in fingers
- Reduced hand sensation
- Difficulty picking up small objects

2. Vascular (Circulatory Damage)

- Fingers turn pale/white in cold or during stress
- Pain attacks due to reduced blood flow
- Poor circulation in fingertips
- This can progress into permanent disability.

3. Musculoskeletal Effects

- Pain in wrists, hands, elbows, shoulders
- Reduced grip strength
- Inflammation of joints and tendons
- Increased likelihood of repetitive strain injuries

Exposure Type	Major Health Effects	Long-Term Consequences
HAV	Nerve damage, vascular problems (white finger), musculoskeletal disorders	Permanent numbness, circulation loss, reduced dexterity
WBV	Spinal damage, lower back pain, digestive issues, fatigue	Chronic back disorders, long-term disability, reduced ability to operate machinery

Exposure Type	Who Is Typically Exposed?	Examples of Tools / Equipment
HAV – Hand-Arm Vibration	Workers using hand-held vibrating tools	Grinders, drills, jackhammers, impact wrenches, needle scalers, sanders, chainsaws
	Construction workers	Breakers, concrete saws, compactors
	Manufacturing & engineering workers	Bench grinders, riveting tools, polishers
	Automotive technicians	Impact guns, orbital sanders, power ratchets
	Forestry & agriculture workers	Chainsaws, hedge trimmers, brush cutters
	Quarry/mining workers	Rock drills, pneumatic chisels

Exposure Type	Who Is Typically Exposed?	Examples of Tools / Equipment
WBV – Whole-Body Vibration	Vehicle/machinery operators	Forklifts, reach trucks, tractors
	Construction plant operators	Excavators, bulldozers, rollers, dumpers
	Transport & logistics drivers	Trucks, buses, vans
	Mining operators	Haul trucks, underground vehicles
	Port & terminal operators	Cranes, straddle carriers, container handlers

Factors Influencing Vibration Exposure

1. Tool condition
2. Work material
3. Operator grip force
4. Posture and seating (WBV)Ground/vehicle conditions
5. Duration & cycle of work

Examples of effective Controls

1. Anti-vibration gloves
2. Low-Vibration tool replacement with exposure reduction tables
3. Installing smooth flooring/seat suspension for WBV.
4. Speed control (vehicles/machinery)

Anti-vibration Gloves EN ISO 10819



Suspension Seat



Vibration Isolation Mounts or Dampers

Gloves work mainly for high-frequency vibration, with minimal effect at low frequencies.
They must be part of broader controls: tool selection, maintenance, exposure time reduction.



Hand-Arm Vibration meters



Whole-Body Vibration platforms



ISO 5349 — Measurement of Hand–Arm Vibration (HAV)

1. ISO 5349 is the international standard that specifies how to measure and evaluate human exposure to hand-transmitted vibration.
2. It consists of two complementary parts:
ISO 5349-1: General Requirements
ISO 5349-2: Practical guidance for workplace measurements
3. These documents define measurement techniques, sensor placement, calculation methods, and exposure metrics.



ISO 5349 — Measurement of Hand–Arm Vibration (HAV)

1. How to Measure Vibration Correctly

ISO 5349 specifies: Tri-axial (x, y, z) measurement of acceleration at the tool–hand interface

- The measurement device must comply with ISO 8041 (vibration instrumentation requirements)
- The sensor must be firmly attached within 10 mm of the grip point
- Use lightweight accelerometers and approved adapters
- Measurements must be taken during representative tool operation

Why ISO 5349 Is Used?

The standard is used to:

1. Assess HAV exposure for risk assessments
2. Determine if workers exceed action/limit values under national laws
3. Support the diagnosis and prevention of Hand–Arm Vibration Syndrome (HAVS)
4. Compare vibration levels between tools

ISO 2631 — Evaluation of Human Exposure to Whole-Body Vibration

1. ISO 2631-1:1997 / 2018 — General Requirements

This is the core WBV standard. It covers:

- How to measure WBV in three axes (x, y, z)
- Use of RMS acceleration to evaluate exposure: Health, comfort, perception, and motion sickness criteria
- Methods for assessing seated and standing workers



Type	Measurement Standard	Notes
HAV (Hand-Arm Vibration)	ISO 5349-1 & ISO 5349-2	Tri-axial tool-handle measurement
WBV (Whole-Body Vibration)	ISO 2631-1 & ISO 2631-5	Seat pad / platform measurement

Control Measures Following Excessive Vibration Exposure

When Exposure Exceeds the Action Value (EAV)?

Required Steps:

1. Review work practices – check tool usage time, operator technique, unnecessary exposure.
2. Improve maintenance – sharpening, lubrication, replacement of worn components.
3. Introduce low-vibration tools or attachments.
4. Implement rotation / reduced exposure durations.
5. Train workers on correct grip force, posture, damping methods e
6. Health surveillance for workers exposed above EAV.

Control Measures Following Excessive Vibration Exposure

When Exposure Exceeds the Limit Value (ELV)

This indicates unacceptable risk — work must not continue unless exposure is immediately reduced.

Required Steps:

1. Immediate cessation or modification of the task.
2. Engineering controls: anti-vibration mounts, suspended seats (WBV) isolation handles, tool redesign (HAV)
3. Review of equipment selection: replace high-vibration equipment.
4. Redesign the task: automation, mechanisation, alternative method.
5. Re-monitor exposure before allowing work to resume.
6. Investigate root cause of why ELV was exceeded — poor maintenance? misuse? incorrect data?
7. Report and document exceedance according to legal requirements.

1. What is the difference between sound and noise?
2. What unit is used to measure noise?
3. What does dB(A) represent?
4. Name one type of noise.
5. At what level does noise become hazardous?
6. What is the exposure limit under Maltese law?
7. What is the first step in noise risk management?
8. Name one engineering control for noise.
9. What does SNR stand for in hearing protection?
10. What is HAV?

11. What syndrome is linked to HAV?
12. What is WBV?
13. Name one occupation at risk of WBV.
14. Why is prevention critical for HAV?
15. What device measures personal noise exposure over time?
16. What does the law require if upper action values are exceeded?
17. What is the purpose of audiometric testing?
18. Why should workers be trained on noise hazards?

Next: Lecture 4: Physical Hazard Control

Strategies: Engineering, Administrative & PPE

Focuses on practical ways to control physical hazards using the hierarchy of controls. Engineering controls include isolation, enclosure, damping, shielding, ventilation, noise barriers, vibration mounts, and machine safeguarding elements. Administrative controls (work rotation, exposure scheduling, maintenance regimes) are discussed along with PPE selection and limitations.

