

Managing Physical Hazards

**Lecture Title: Physical Hazard Control Strategies:
Engineering, Administrative & PPE**

Lecturer: Chris Camilleri

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**Undergraduate Diploma in
Occupational Health and Safety**

Welcome and Objectives

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.



The Hierarchy of Controls



Engineering Controls



Administrative Controls



Personal Protective Equipment (PPE)

- Last Line of Defense
- Requires Proper Fit & Use
- Limited Protection



Physical Hazard Control Strategies:

Engineering, Administrative & PPE

1. This lecture focuses on how physical hazards are controlled in workplaces
2. Emphasis is on risk reduction, not hazard recognition
3. Builds on earlier lectures where hazards and exposures were already identified
4. Does not focus on exposure limits, measurements, or health effects
5. Examines how controls change the system, not just worker behaviour

How is risk actually reduced in real working conditions?



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

Lecture 5 — Radiation Hazards: Ionising and Non-Ionising

Lecture 6 — Lighting, Visibility, and Workplace Ergonomics

Lecture 7 — Machinery, Mechanical Hazards & Machine Safeguarding

Lecture 8 — Workplace Environment Hazards: Slips, Trips, Falls, and Confined Spaces

Lecture 9 — Physical Hazard Control Strategies: Engineering, Administrative & PPE

Lecture 10 — Integrated Physical Hazard Management & Continuous Improvement 18th May

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



From Hazard Identification to Risk Control

1. Identifying hazards $\neq$ controlling risk

- Spotting a hazard only tells us what could cause harm
- Risk remains unchanged until something physically or organisationally changes
- Many incidents happen in workplaces where hazards were already known

Knowing about a risk does not protect people — action does.



From Hazard Identification to Risk Control

2. Risk assessment must drive decisions

- The purpose of a risk assessment is not the form
- It should answer:
 - What needs to change?
 - Who must act?
 - By when?
- A good risk assessment ends with:
 - Eliminated hazards,
 - Reduced exposure, Improved design or systems

If nothing changes
on the shop floor,
risk has not been
managed



From Hazard Identification to Risk Control

3. Controls must be tangible and verifiable

- Effective controls are:
 - Visible (you can see them)
 - Testable (you can check them)
 - Sustainable (they still work tomorrow)

☐ Fixing the floor vs putting up a warning sign

☐ Guarding a machine vs writing a procedure

Controls should survive people, shifts, and time pressure



From Hazard Identification to Risk Control

4. Documentation alone does not prevent harm

- Documents support safety — they are not safety
- Over-reliance on paperwork creates false reassurance:
 - “The risk assessment was done” $\neq$ safe work
- Real protection comes from engineering, design, and supervision



Why Knowing the Hazard Is Not Enough

1. Many accidents occur where hazards were already known
2. Controls may exist but be ineffective
3. Focus shifts from “what is the hazard?” to “what failed?”



If We Know the Risks:

Why Do Accidents Still Happen?

1. Controls fail, degrade, or are not fully implemented
2. Safety relies too much on people instead of systems
3. Poor design allows exposure to persist
4. Sets the risk-based tone for the lecture



Risk Control vs Risk Assessment:

Understanding the Difference

1. Risk assessment identifies and evaluates risk

Hazards are recognised, analysed, and prioritized.

2. Risk control reduces exposure and harm

The hazard is removed, isolated, or its impact reduced.

3. Assessment informs — control protects

Risk is only reduced when physical or organisational change occurs.



What Do We Mean by “Control” in Occupational Health & Safety?

1. Control means deliberately changing the work system to reduce risk.
2. Control works by altering:
 - the source of the hazard,
 - the pathway through which harm occurs,
 - or the level of exposure to the worker.

Strong controls reduce reliance on human behaviour and compliance.



The Hierarchy of Controls:

A Decision-Making Tool

1. The hierarchy of controls is a structured framework for selecting the most effective risk control measures.
2. It is not a checklist, but a decision-making tool that ranks controls:
 - by their effectiveness in reducing risk, &
 - by their dependence on human behaviour and compliance.

The hierarchy applies across **all physical hazards** and guides duty-holders to prioritise controls that change the system rather than rely on people.



Control Strength & Dependence on Human Behaviour

- The strength of a control depends on how much it relies on human behaviour.
 - Engineering controls are the strongest, as they are built into the system and require minimal behavioural input.
 - Administrative controls rely on people following procedures and instructions.
 - Personal Protective Equipment (PPE) is the weakest control, as it depends entirely on correct and consistent use by the worker

Controlling the Hazard vs Managing Exposure

Control strategies differ in what they act upon:

1. Engineering controls act directly on the hazard itself, removing or isolating it.
2. Administrative controls manage exposure by controlling time, access, or work organisation.
3. Personal Protective Equipment (PPE) does not control the hazard and only reduces the impact on the worker.

Engineering Controls



Engineering Controls:

The Primary Line of Defence

1. Engineering controls are the first and preferred choice in managing physical hazards.
2. They are integrated into equipment, processes, and workplace design, acting directly on the hazard.
3. Because they operate independently of worker behaviour, they provide consistent and reliable protection.



Why Engineering Controls Are Preferred for Physical Hazards

1. Engineering controls are preferred because they reduce reliance on training, supervision, and individual compliance.
2. They can protect multiple workers at the same time and remain effective across shifts, over time, and under normal working pressures.



Engineering Control Principles: An Overview

1. Engineering controls reduce risk by physically changing how hazards are **generated, contained, or transmitted**.
2. Key principles include **eliminating** or **substituting** hazards, **isolating or enclosing** sources of harm, and reducing energy through shielding, damping, absorption, or ventilation.
3. Where possible, **automation and interlocks** are used to prevent exposure by design rather than by instruction.



Elimination and Substitution as Risk Control Strategies

1. **Elimination** and **substitution** are the most effective forms of risk control because they address the hazard at its source.
2. They involve **removing the hazard** entirely or replacing it with a less hazardous process, material, or equipment.
3. Where feasible, these approaches provide the highest level of **risk reduction** and should always be considered first.



Isolation: Separating People from the Hazard

1. Isolation controls risk by physically separating people from the hazard.
2. This is achieved through distance, barriers, guarding, or remote operation, limiting exposure without eliminating or altering the hazard itself.

Enclosure: Containing the Hazard at Source

1. Enclosure controls risk by containing the hazard at or close to its source, either fully or partially.
2. Examples include noise enclosures, machine housings, and guarded systems.
3. To remain effective, enclosures must maintain their physical integrity and be supported by ongoing inspection and maintenance.



Shielding: Interrupting the Hazard Pathway

1. Shielding reduces risk by placing a physical barrier between the hazard source and the worker.

- Interrupts the pathway of harm
- Commonly used for radiation, thermal, and mechanical hazards
- Effectiveness depends on correct design and positioning

Damping and Absorption: Reducing Transmitted Energy

Damping and absorption reduce risk by limiting the transmission of energy from the hazard.

- Reduce the transmission of vibration or sound
- Achieved through special materials and mountings
- Often misunderstood or incorrectly applied, reducing effectiveness

Ventilation as an Engineering Control (Strengths and Limits)

1. Ventilation controls risk by removing or diluting hazardous agents from the workplace.

- Reduces concentrations of airborne contaminants
- Not always effective for high-energy or rapidly generated hazards
- Requires correct design, airflow, and ongoing maintenance to remain effective

Automation and Interlocking Systems

1. Automation and interlocking systems control risk by removing the need for direct human involvement.

- Reduce the need for human presence or intervention
- Prevent unsafe operation through built-in safeguards and interlocks
- Can introduce new risks if poorly designed, bypassed, or inadequately maintained



Applying Engineering Controls Across Physical Hazards

1. Engineering control principles are consistent across all physical hazards.
2. The same approaches apply to **noise, heat, vibration, radiation, and machinery**
3. Control strategies are **transferable concepts**, not hazard-specific solutions



Designing:

Normal Operations vs Non-Routine Tasks

1. Engineering controls must account for both routine and non-routine work.
2. Maintenance, cleaning, and repairs are often overlooked during design
3. These activities typically involve higher risk exposures
4. Safeguards are frequently temporarily removed or bypassed, increasing risk



When Engineering Controls Fail

1. Engineering controls can fail when system weaknesses are introduced or unmanaged.
2. Poor design that does not reflect real working conditions
3. Inadequate inspection and maintenance
4. Safeguards bypassed or defeated to get the job done
5. Process or task changes not reassessed for risk



Common Engineering Control Failure Mechanisms

1. Engineering controls often fail due to how they are applied and managed.
2. Controls exist but are not used or not enforced
3. Effectiveness is degraded over time (wear, damage, poor maintenance)
4. Controls are not suited to real working conditions or actual task demands



Administrative Controls



Administrative Controls: What They Actually Do

1. Administrative controls manage risk by controlling how and when work is carried out.
2. Define how work is done through procedures, rules, and systems
3. Control when and for how long exposure occurs
4. Do not remove or change the hazard itself



Administrative Controls Do Not Remove Hazards

1. Administrative controls manage risk while the hazard remains present.
2. The hazard is still in place
3. Protection relies on worker compliance and correct behaviour
4. Supervision, monitoring, and discipline are critical to effectiveness



Example of Common Administrative Control Measures

1. Administrative controls manage risk through rules, systems, and work organisation.
2. Work rotation to limit individual exposure
3. Exposure time limits and scheduling
4. Permits to work for higher-risk activities
5. Maintenance schedules to control deterioration of controls
6. Training and procedures to guide safe working practices



Managing Exposure Instead of Controlling Risk

1. Administrative controls focus on managing exposure rather than removing risk.
2. Reducing exposure does not eliminate the hazard
3. Often used where engineering controls are missing or weak
4. Should support engineering controls, not replace them



Human Reliability & Administrative Controls

1. The effectiveness of administrative controls is limited by human reliability.
2. Performance can be affected by fatigue and distraction
3. Experience and competence vary between individuals
4. Time pressure increases the likelihood of error and non-compliance



Why Administrative Controls Fail Over Time

1. Administrative controls tend to weaken as work systems drift.
2. Normalisation of deviation becomes accepted as standard practice
3. Poor or inconsistent supervision undermines compliance
4. Procedural drift occurs as shortcuts develop
5. Inadequate review and updating fails to reflect changing conditions



Administrative Controls as Support: Not Substitutes

1. Administrative controls must support engineering controls, not replace them.
2. They should sit on top of effective engineering controls
3. They are never an adequate primary solution for high-risk physical hazards



Personal Protective Equipment (PPE)



Personal Protective Equipment:

The Last Line of Defence

1. Personal Protective Equipment (PPE) provides the final barrier between the worker and the hazard.
2. Used when engineering and administrative controls are insufficient
3. Does not control the hazard itself, only limits its impact
4. Effectiveness is highly dependent on correct and consistent human use

What PPE Does? and Does Not? Control?

1. PPE limits the impact of a hazard on the worker: it does not control the hazard itself.
2. Reduces individual exposure at the point of contact
3. Does not eliminate or reduce the hazard at source
4. Can create a false sense of safety if relied on as the main control



PPE Selection for Physical Hazards

1. PPE must be selected based on the specific hazard and level of exposure.
2. Selection must be hazard-specific (e.g. noise, thermal, mechanical, radiation)
3. Exposure level and duration must be considered to ensure adequate protection
4. PPE must be compatible with other PPE to avoid reducing effectiveness



Fit, Comfort, Compatibility and Wear Time

1. The effectiveness of PPE depends on how well it can be worn and maintained over time.
2. Poor fit significantly reduces the level of protection
3. Discomfort increases the likelihood of non-compliance
4. Wear duration and exposure time must be considered to ensure adequate protection



Behavioural Dependence of PPE

1. The effectiveness of PPE relies entirely on human behaviour.
2. PPE must be worn correctly to provide the intended level of protection
3. PPE must be worn consistently, whenever exposure occurs
4. PPE must be properly maintained to remain effective over time



Common Reasons PPE Fails to Protect Workers

1. PPE often fails due to behavioural and organisational factors.
2. Incorrect use or improper wearing of PPE
3. Poor supervision and lack of enforcement
4. Inadequate or ineffective training
5. Cultural factors, where PPE rules are not taken seriously



When PPE Is Necessary and Appropriate

1. PPE is appropriate when residual risk remains after higher-level controls are applied.
2. Used to manage residual risk that cannot be eliminated
3. Often required for temporary activities
4. Commonly necessary during non-routine tasks
5. Essential in emergency situations where other controls are not feasible



Control Effectiveness & Performance



Having Controls in Place vs Controls Working

The presence of controls does NOT guarantee effective risk reduction.

1. Controls may exist but still be ineffective in practice
2. Verification and monitoring are required to confirm they work as intended
3. Real-world use, not design alone, determines effectiveness



Control Effectiveness Over Time

Control effectiveness can reduce over time if not actively managed.

1. Wear, damage, and deterioration reduce performance
2. Process and task changes may invalidate existing controls
3. Increased workload or pace places controls under stress
4. Reduced vigilance leads to controls being overlooked or bypassed



Leading and Lagging Indicators for Control Performance

Control performance must be monitored using a mix of leading and lagging indicators.

1. Lagging indicators reflect past outcomes, such as incidents, injuries, and near-misses
2. Leading indicators provide early warning, including inspections, safety observations, and maintenance result



Detecting Control Drift in Physical Hazard Management

1. Control drift occurs when effective controls gradually lose their effectiveness over time.
2. Standards erode slowly, often without being noticed
3. Early warning signs are present but frequently ignored
4. Detecting and correcting drift is a management responsibility, not a worker failure



Legal & Good Practice Context



Legal Duty to Control Physical Hazards

1. Employers have a legal duty to reduce risks from physical hazards.
2. The duty is to prevent or reduce risk, not simply identify hazards
3. Hazards must be controlled at source where reasonably practicable



From Legal Compliance to Good Practice

- 1. Compliance = Minimum standard**
Meeting legal requirements is the starting point, not the goal
- 2. Good practice = Beyond compliance**
Proactive risk reduction and application of industry standards
- 3. Continuous improvement**
Ongoing review, learning, and enhancement of controls



Key Messages from Physical Hazard Control Strategies

1. **Control strategy > paperwork**

Real risk reduction comes from effective controls, not documentation

2. **Engineer the risk out first**

Design, guarding, isolation before relying on behaviour

3. **People-dependent controls = fragile**

Procedures, PPE, and training can fail under pressure or human error



Why Control Strategies Require Ongoing Review

1. Hazards remain

The source of risk rarely disappears

2. Systems change

People, processes, and environments evolve over time

3. Controls degrade

Wear, bypass, and drift reduce effectiveness



Case Scenario: Bhopal Gas Disaster (1984)

Total failure of engineering controls

1. What happened

- Toxic gas (MIC) leaked from a pesticide plant
- Thousands killed, tens of thousands injured

2. What failed (Hierarchy view)

- Engineering controls (completely failed)
- Refrigeration system switched off
- Gas scrubber ineffective
- Alarms not functioning

Multiple engineered safety layers were either:

1. Disabled
2. poorly maintained or
3. not designed properly

https://eng.libretexts.org/Bookshelves/Industrial_and_Systems_Engineering/Process_Dynamics_and_Controls_%28Woolf%29/01%3A_Overview/1.1%3A_Introduction_to_Process_Control-_Bhopal_Three_Mile_Island



Case Scenario: Bhopal Gas Disaster (1984)

Total failure of engineering controls

1. This was not one failure — it was the collapse of every engineered barrier.
2. When engineering fails, admin + PPE cannot compensate
3. Layered protection = only works if layers are alive



Case Scenario: BP Texas City Refinery Explosion (2005) *Control drift & system failure*

1. What happened

- Vapour cloud explosion
- 15 dead, 180 injured

2. What failed

- **Engineering:** Faulty instrumentation (wrong level readings)
- **Administrative:** Alarms ignored, Poor startup procedures, Inadequate supervision
- **System level:** Cost cutting, Poor safety culture



Case Scenario: BP Texas City Refinery Explosion (2005) *Control drift & system failure*

1. The controls existed: but they were no longer reliable.
2. Controls degrade silently
 - “Installed” ≠ “Effective”



1. A risk assessment identifies a serious hazard and actions are assigned, but months later nothing has changed on site. From a professional perspective, what has failed?
2. Which control is stronger: warning signs or machine guarding? Why?
3. Why are engineering controls considered more reliable than administrative controls?
4. In a well-managed organisation, when is it acceptable for PPE to become the dominant control measure?
5. What is the key difference between controlling a hazard and managing exposure?



6. Why do accidents still happen even when controls are in place?
7. Give one example where PPE might actually create risk.
8. What is “control drift”?
9. Why are administrative controls considered “fragile”?
10. If you had to summarise the hierarchy of control in one sentence, what would it be?



Next: Lecture10: Integrated Physical Hazard Management

This session covers physical hazards linked to workplace conditions—flooring, surfaces, obstacles, contamination, footwear, and poor housekeeping. Students explore friction requirements, environmental influences, and design factors. Confined space physical hazards (oxygen deficiency, mechanical energy, engulfment) and permit-to-work requirements are also reviewed.

