

Module 3: Chemical Safety and Hazard Management

3.2

Lab Hazards and Risk Management Chemical, biological, and physical hazards

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Learning Outcomes

After completing this session, students will be able to:

1. Identify and classify different types of chemical, biological, and physical hazards encountered in laboratory, industrial, and clinical settings.
2. Explain the mechanisms by which these hazards affect the human body.
3. Discuss methods for hazard assessment, risk evaluation, and control measures.



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Chemical, biological, and physical hazards

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Safe handling of acids, bases, and volatile solvents

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Reflection Spot



"Am I aware of the hazards around me, and am I doing enough to stay safe?"

Chemical Hazards

Definition: Chemical hazards are substances that can cause harm to health or safety through chemical interactions or toxic effects when inhaled, ingested, or contacted through skin or eyes.

Examples: Acids, solvents, pesticides, heavy metals, and flammable liquids.



Chemical Hazards

Chemical hazards arise from exposure to toxic, corrosive, flammable, or reactive substances.

Chemical Hazard Examples

Example 1

Example 2



**Toxic
Chemicals**

Benzene

Lead



Corrosives

Hydrochloric acid

Sodium hydroxide



Flammables

Ethanol

Acetone



**Reactive
Chemicals**

Peroxides

Picric acid

Chemical Hazards

Types of Toxicity

Acute Toxicity

Immediate harm caused by a substance.



Chronic Toxicity

Long-term exposure causing gradual health issues.



Carcinogens

Substances that can cause cancer development.



Mutagens and Teratogens

Agents causing genetic mutations and birth defects.



Biological Hazards

Definition: Biological hazards, or biohazards, are biological agents or materials (such as microorganisms, viruses, or toxins) that pose a threat to human or animal health.

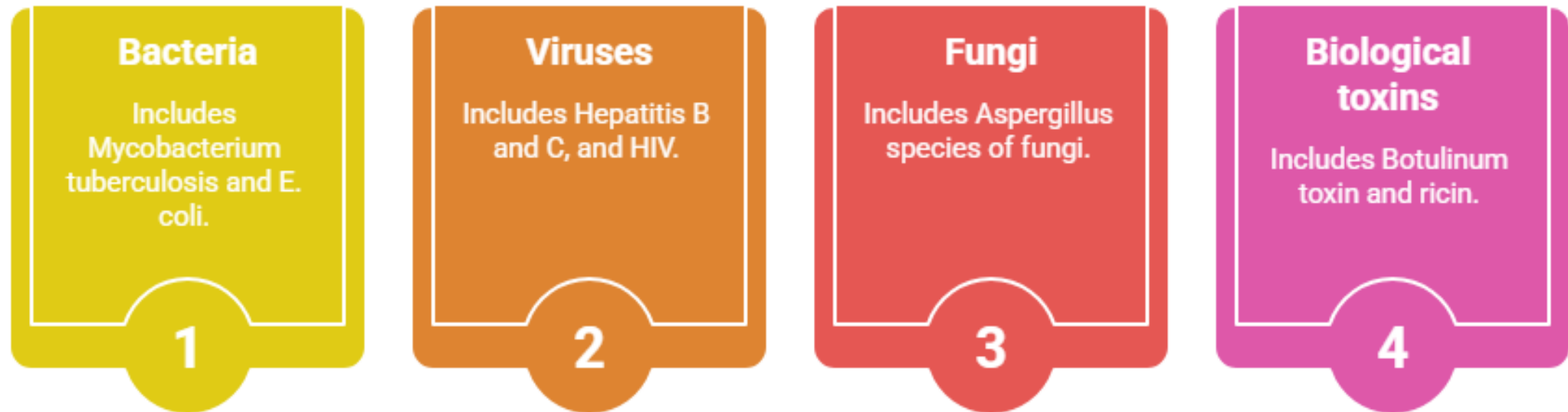
Examples: Bacteria (E. coli), viruses (HIV, Hepatitis B), fungi (Aspergillus), and biological waste.



Biological Hazards

Biological hazards, or biohazards, involve exposure to infectious agents or biological materials.

Examples:



Biological Hazards

Sources:

Clinical samples, contaminated instruments, animal handling, and waste disposal

Risk groups (WHO classification):

- Group 1: Low risk (e.g., *Lactobacillus*)
- Group 2: Moderate risk (e.g., *Salmonella*)
- Group 3: High individual risk (e.g., *Mycobacterium tuberculosis*)
- Group 4: High risk with no treatment (e.g., Ebola virus)

Physical Hazards

Definition: Physical hazards are environmental or mechanical factors that can cause injury or damage without necessarily involving chemical or biological agents.

Examples: Radiation, noise, vibration, extreme temperatures, and sharp or moving machinery parts.

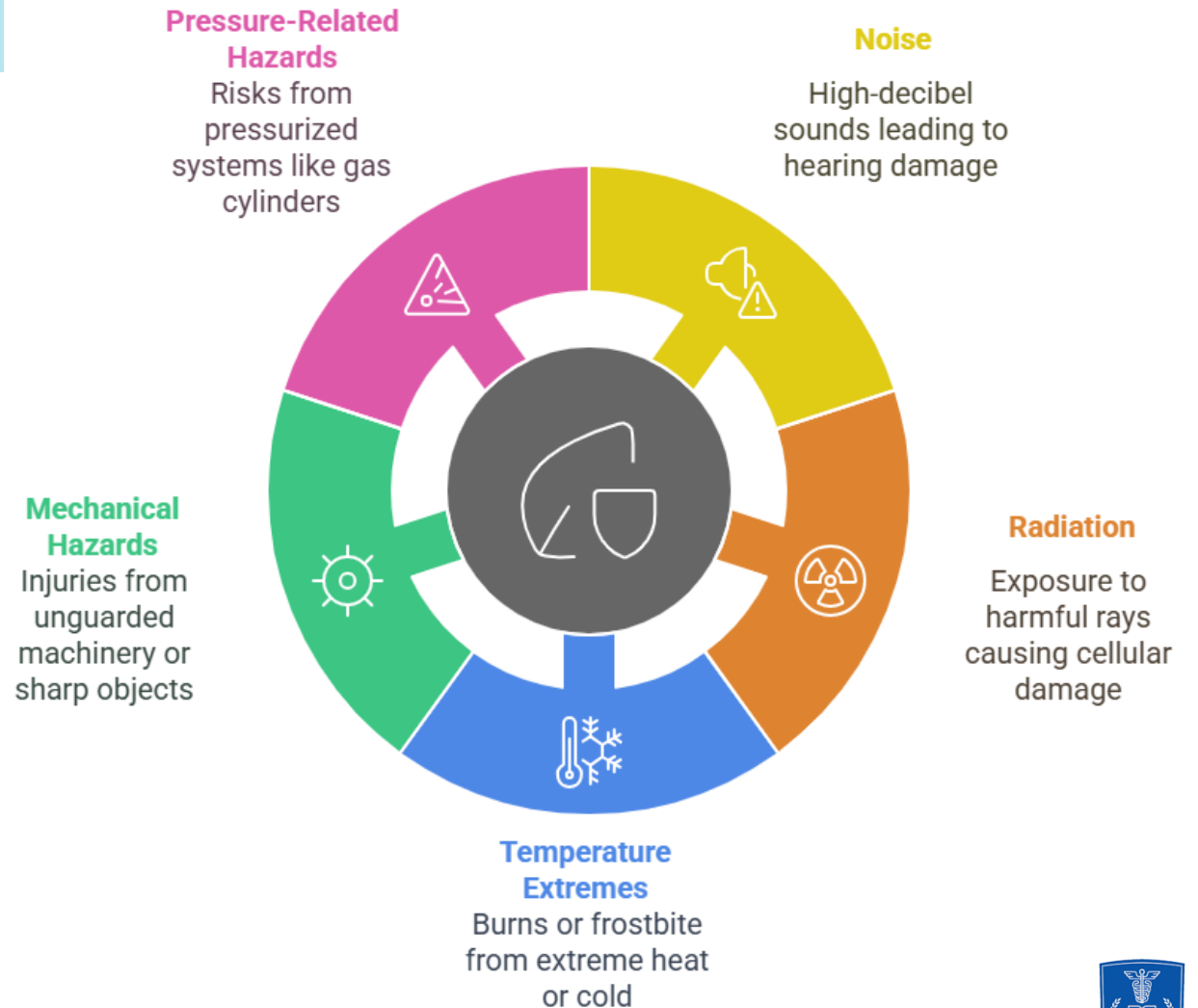
Physical Hazards

Physical hazards are environmental factors that can cause harm without direct contact with substances.

Additional classifications:

- **Ergonomic hazards:** Repetitive motions, poor posture
- **Vibration and lighting hazards:** Power tools, inadequate lighting in workspaces

Physical Hazards and Their Impacts



Mechanisms of Hazard- Induced Harm to the Human Body

Chemical Hazards – Mechanism of Action

Chemical agents can harm the body through:

- **Inhalation, ingestion, skin contact, or injection.**
- **Once inside, chemicals may:**
 - **Disrupt cellular processes (e.g., cyanide inhibits cellular respiration).**
 - **Cause DNA mutations (e.g., benzene → leukemia).**
 - **Trigger allergic reactions (e.g., latex, formaldehyde).**
 - **Damage organs (e.g., liver damage from acetaminophen overdose).**

Target organs: Liver, kidneys, lungs, skin, CNS.



Biological Hazards – Mechanism of Action

Biological agents cause harm via:

- **Infection and replication in host cells (e.g., viruses like HIV).**
- **Toxin production (e.g., *Clostridium botulinum* → neurotoxicity).**
- **Immune system activation, leading to inflammation or hypersensitivity.**
- **Tissue invasion and destruction (e.g., *Mycobacterium tuberculosis* in lungs).**

Results: Disease, immune suppression, chronic conditions.

Biological Hazards – Mechanism of Action

Physical agents affect the body through:

- **Mechanical injury (e.g., cuts, crush injuries from equipment).**
- **Thermal effects (e.g., burns, hypothermia).**
- **Radiation exposure:**
 - **Ionizing radiation damages DNA and may cause cancer.**
 - **Non-ionizing radiation (UV) can lead to skin damage or eye injury.**
- **Noise causes hearing loss by damaging cochlear hair cells.**
- **Vibration and poor ergonomics lead to musculoskeletal disorders.**



Hazard Assessment, Risk Evaluation, and Control Measures

Hazard Assessment

The process of identifying potential hazards in a workplace or environment.

Hazard Assessment Process



Identify Hazards

Recognize potential dangers in the workplace



Determine Exposure Routes

Understand how hazards can affect workers



Collect Data

Gather information from SDS and regulations



Risk Evaluation

$$\text{Risk} = \text{Probability of harm} \times \text{Severity of harm}$$

Key Components:

- **Likelihood of exposure:** How often and how likely is the contact with hazard?
- **Severity of consequences:** Minor injury vs. fatality.
- **Who is at risk?** (e.g., lab workers, maintenance staff)

Tools:

- **Risk Matrix** (Low, Medium, High Risk)
- **Job Safety Analysis (JSA)**
- **Exposure monitoring** (e.g., air sampling, biological monitoring)



Control Measures

Elimination

Remove the hazard entirely



Substitution

Replace with a safer alternative



Engineering Controls

Isolate people from the hazard



Administrative Controls

Change work practices



Personal Protective Equipment

Use PPE as a last defense



Safe Handling of Acids, Bases, and Volatile Solvents

General Safety Principles

- **Always follow laboratory Standard Operating Procedures (SOPs).**
- **Wear appropriate Personal Protective Equipment (PPE): gloves, goggles/face shield, lab coat, and closed shoes.**
- **Work in a well-ventilated area or fume hood, especially for volatile solvents.**
- **Label all containers clearly with chemical name, concentration, and hazard symbols.**
- **Know the location and use of emergency equipment (e.g., eyewash station, safety shower, fire extinguisher, spill kit).**



Handling Acids

Examples: Hydrochloric acid (HCl), Sulfuric acid (H₂SO₄), Nitric acid (HNO₃)

- **Always add acid to water**, never the reverse, to avoid exothermic splashes.
- Use acid-resistant containers and glassware.
- Store acids separately from bases and organic solvents.
- Use secondary containment for storage to prevent spills.
- Clean small spills with a neutralizing agent (e.g., sodium bicarbonate) under supervision.

Handling Bases

Examples: Sodium hydroxide (NaOH), Potassium hydroxide (KOH), Ammonium hydroxide (NH₄OH)

- Handle with caution as bases can cause deep tissue damage.
- Dissolve slowly in water with stirring to avoid heat buildup.
- Use containers resistant to alkali corrosion (e.g., polypropylene).
- Clean spills with a mild acid (e.g., vinegar or citric acid) if trained and safe to do so.



Handling Volatile Solvents

Examples: Acetone, Ether, Chloroform, Methanol, Toluene

- Work in a **certified fume hood** to avoid inhalation of vapors.
- Keep away from ignition sources—many are **highly flammable**.
- Store in **flammable safety cabinets**, in tightly sealed containers.
- Avoid prolonged skin contact—use chemical-resistant gloves (e.g., nitrile).
- Do not pipette by mouth; use mechanical pipetting aids.



Waste Disposal

- Segregate acid/base waste and volatile solvent waste.
- Use properly labeled containers for chemical waste.
- Never pour concentrated acids, bases, or solvents down the sink unless neutralized and authorized.
- Follow institutional or regulatory disposal guidelines.



First Aid for Chemical Exposure

General Principles

- **Stay calm and act quickly.**
- **Remove the victim from exposure source** (e.g., fumes, spills).
- **Use PPE** if assisting to avoid secondary exposure.
- **Call for medical help immediately** if symptoms are serious.

Skin Contact

- Immediately flush the affected area with **copious amounts of water** for **at least 15–20 minutes**.
- Remove contaminated clothing and jewelry carefully.
- **Do not apply creams or ointments** unless advised by a healthcare professional.
- Seek medical attention, especially for concentrated acids, alkalis, or corrosive substances.

Eye Contact

- Rinse eyes immediately using an **eyewash station** or clean running water.
- Hold eyelids open and flush continuously for **at least 15 minutes**.
- Avoid rubbing the eyes.
- Seek urgent medical attention.

Inhalation of Chemical Vapors or Fumes

- Move the person to fresh air immediately.
- Loosen tight clothing to aid breathing.
- If breathing is difficult, administer **oxygen** (if trained) and seek emergency care.
- Perform **CPR** if the person is not breathing and you're trained to do so.



Ingestion of Chemicals

- **Do not induce vomiting** unless directed by medical personnel.
- Rinse the mouth with water gently.
- Identify the chemical ingested and provide this information to medical responders.
- Seek immediate medical attention.

Specific Measures

- **Acid or alkali burns:** After rinsing, apply sterile dressing and get medical help.
- **Volatile solvent exposure:** Ensure fresh air and monitor for CNS symptoms (e.g., dizziness, confusion).

Disposal and Waste Management

Proper chemical waste disposal is essential to ensure **safety, environmental protection, and regulatory compliance.**



Classification of Chemical Waste

- **Hazardous Waste:** Includes toxic, corrosive, flammable, or reactive chemicals (e.g., acids, solvents, heavy metals).
- **Non-Hazardous Waste:** Includes buffers, salts, or dilute solutions (if confirmed safe).
- **Biological Waste:** Cultures, infectious materials—requires sterilization before disposal.
- **Sharps and Broken Glass:** Must be disposed in puncture-resistant containers.



Collection and Segregation

- Always **label waste containers** with chemical name(s), concentration, and hazard symbols.
- Do **not mix incompatible wastes** (e.g., acids with bases, oxidizers with organics).
- Use **separate containers** for different waste types:
 - Acid/base waste
 - Organic solvents
 - Heavy metals
 - Biological waste

Storage of Waste

- Store in **designated, well-ventilated areas**, away from heat or direct sunlight.
- Use **leak-proof, chemically resistant containers** with secure lids.
- Maintain a **chemical waste logbook** for tracking.



Disposal Procedures

- Follow institutional and local **environmental health & safety (EHS)** or **CPCB/Bio-Medical Waste Rules**.
- Coordinate with **authorized waste disposal agencies**.
- Never dispose of hazardous chemicals in:
 - Regular trash
 - Sinks or drains (unless properly neutralized and permitted)



Waste Minimization Strategies

- **Plan experiments efficiently** to reduce waste generation.
- **Reuse and recycle** where feasible (e.g., solvent distillation).
- Use **microscale techniques** to limit chemical usage.

Emergency Preparedness

- In case of spills, use **chemical spill kits** and follow spill response protocols.
- Report all incidents to the **laboratory supervisor or safety officer**.

