People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
Mohamed Khider University – Biskra
Faculty of Science and Technology
Department of Process Engineering

HSE
In Industrial Installations

Pedagogical Handout

Designed for:

2nd Year Engineering Students

Prepared by

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Academic Year: 2025/2026

Official Course Programs

Semestre: 3
Unité d'enseignement: UED2.1
Matière 1: HSE Installations industrielles
VHS: 22h30 (cours: 1h30)
Crédits: 1
Coefficient: 1

Objectifs de l'enseignement

- Identifier et évaluer le risque ;
- Mettre en œuvre les méthodes de prévention appropriées ;
- Contrôler la réalité et l'efficacité des dispositifs mis en place.

Connaissances préalables recommandées

Contenu de la matière

Chapitre 1 : Introduction à l'évaluation et à la maîtrise des risques, Analyse des accidents
7 semaines

1.1 Comprendre les notions de base (danger, risque) et identifier les acteurs de la prévention ;
1.2 Maîtriser les indicateurs relatifs aux accidents du travail (taux de fréquence, taux de gravité, ...) et aux maladies professionnelles ;
1.3 Observer et analyser les risques liés à une situation de travail ;
1.4 Elaborer un arbre des causes ;

Chapitre 2 : Introduction à la santé au travail et à la protection de l'environnement
8 semaines

2.1 Identifier les principaux aspects en matière d'hygiène et de santé publique ;
2.2 Connaître les notions d'hygiène de l'habitat ;
2.3 Connaître les principaux domaines de la protection de l'environnement ;
2.4 Appréhender la problématique du développement durable ;
2.5 identifier le rôle et la mission des différents organismes en matière de santé et sécurité du travail et de santé publique.

Mode d'évaluation : Examen final: 100 %.

Références bibliographiques:
(Selon la disponibilité de la documentation au niveau de l'établissement, Sites internet...etc.)

Intitulé de la Licence: Génie des procédés *Année: 2021-2022*

Preface

This pedagogical manual is designed for second-year Process Engineering students, in accordance with the official syllabus of the Ministry of Higher Education and Scientific Research. It covers the entire program of the module "**Health, Safety and Environment (HSE) in Industrial Installations**."

The aim of this document is to accompany students throughout the semester by providing a clear, rigorous, and structured synthesis of the course, illustrated with practical examples and application exercises. It is intended both as an indispensable complement to the lectures and as an effective tool for preparation for tutorial sessions.

The document is organized around two main chapters:

- **Chapter One:** Introduction to Risk Assessment and Accident Analysis, covering fundamental HSE concepts, prevention stakeholders, safety performance indicators, risk analysis methodologies, root cause analysis techniques, and risk families.
- **Chapter Two:** Occupational Health and Environmental Protection, addressing work-related diseases, industrial hygiene, environmental monitoring, environmental management systems, waste management, and sustainability.

Each chapter is structured progressively to facilitate learning: essential theoretical reminders, methodological developments, practical application exercises with detailed solutions, and integrated case studies to consolidate acquired knowledge.

This document is intended as a practical working tool. It does not replace the consultation of specialized reference books for further in-depth study.

I would like to express my sincere gratitude to the authors of the various scientific references and pedagogical materials consulted, which greatly facilitated the writing and structuring of this document. I sincerely hope that this manual will effectively guide students throughout their academic journey and enable them to master this essential discipline of Process Engineering.

Dr. Wassila GRINE

University of Mohamed Khider – Biskra

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Health, Safety and Environment (HSE)

In Industrial Installations

Chapter One: Introduction to Risk Assessment and Accident Analysis

Description: Introduction to Safety Systems for Industrial Engineering



Five-Session Roadmap

Section 1: Introduction to HSE & Fundamental Concepts
Section 2: Prevention Stakeholders & Safety Performance Indicators
Section 3: Risk Analysis Methodology
Section 4: Root Cause Analysis Methods
Section 5: Risk Families & Integrated Case Study

Chapter I: Introduction to Risk Assessment and Accident Analysis

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Introduction

This chapter is structured into five main sections. Each section addresses a key component of risk assessment and accident analysis from fundamental concepts to root cause analysis and integrated case studies providing a progressive and comprehensive understanding of the subject.

SECTION 1: Introduction to HSE & Fundamental Concepts

1. Fundamental Concepts of Health, Safety and Environment (HSE)

1.1. Learning Objectives

At the end of this section, the learner will be able to:

- Define the concept of Health, Safety and Environment (HSE) as an integrated management system;
- Distinguish between the three interdependent pillars of HSE;
- Differentiate between fundamental concepts: hazard, risk, accident, and incident;
- Classify hazards according to their nature and type;
- Explain the fundamental equation of risk.

1.2. Introduction: Why HSE Matters

Historical Context

The evolution of industrial safety has been largely shaped by major industrial disasters that occurred throughout the 20th and 21st centuries. These catastrophic events served as catalysts for the development of modern safety regulations and management systems.

Table I.1: Major Industrial Disasters

Disaster	Year	Location	Consequences	Regulatory Impact
Seveso	1976	Italy	Dioxine cloud release	Seveso Directive (EU)
Bhopal	1984	India	Toxic gas leak	15,000+ deaths
Toulouse (AZF)	2001	France	Factory explosion	31 deaths

The evolution of safety thinking has transitioned from a **reactive** approach responding to disasters after they occur to a **proactive strategic approach** where prevention is prioritized. In contemporary industrial contexts, HSE is recognized not merely as a legal compliance obligation but as a **competitive factor** that contributes to operational excellence and organizational sustainability.

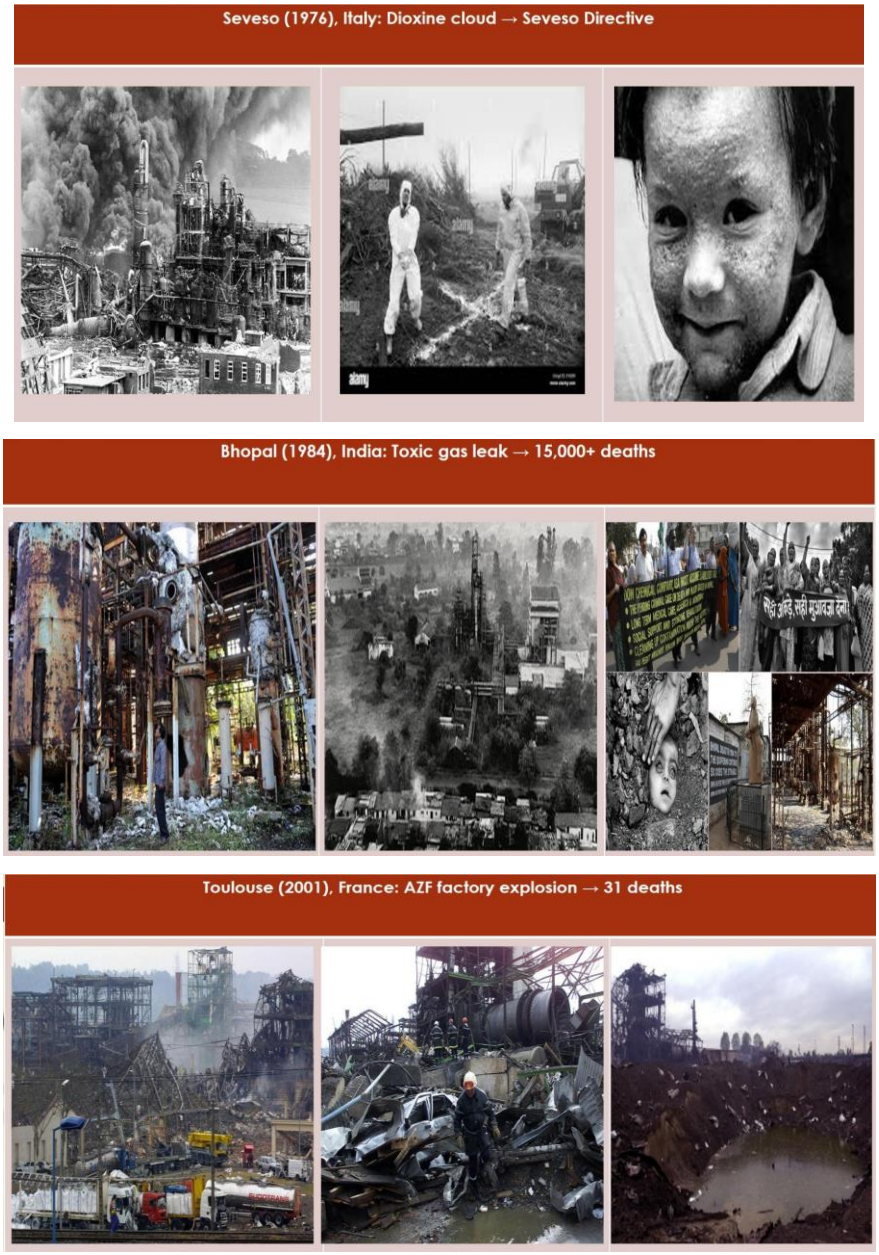


Figure I.1: Major Industrial Disasters - Seveso (1976), Bhopal (1984), Toulouse AZF (2001)

1.3. HSE Management System

1.3.1. Definition

Health, Safety and Environment (HSE) is defined as an integrated management system designed to achieve three primary objectives:

1. **Health:** Protect worker health and prevent occupational diseases;
2. **Safety:** Prevent accidents and ensure the physical integrity of workers;

3. **Environment:** Reduce the environmental impact of industrial activities.

1.3.2. The Three Interdependent Pillars

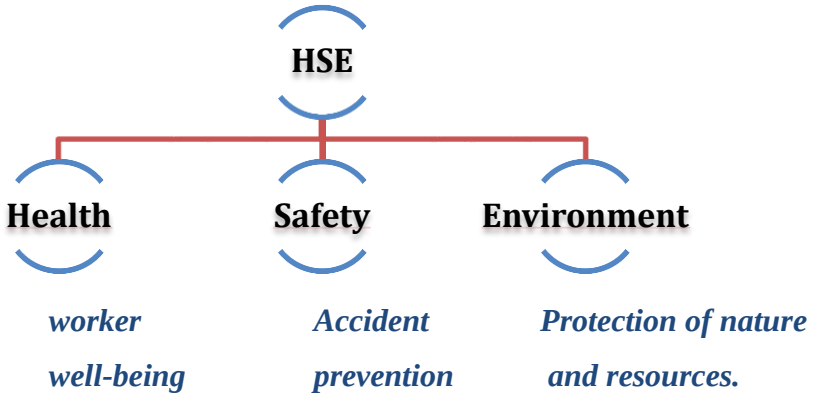


Figure I.2: The Three Pillars of HSE

Table I.2: Comparative Analysis of the Three HSE Components

Component	Primary Focus	Key Concerns	Preventive Measures
Health	Worker well-being	Occupational diseases, mental health, ergonomic stressors	Medical surveillance, ergonomic interventions, psychosocial support
Safety	Accident prevention	Physical injuries, equipment hazards, unsafe behaviors	Engineering controls, training, protective equipment
Environment	Ecological protection	Pollution, waste management, resource consumption	Emission controls, waste treatment, sustainable practices

Note: A balanced focus on Health, Safety, and Environment is essential for a successful HSE system. The formula $H \rightarrow S \rightarrow E$ = *Success & Sustainability* underscores that neglecting any pillar undermines the integrity of the entire system.

1.4. Fundamental Concepts

1.4.1. Core Concept 1: Hazard

Definition: A **hazard** is defined as a source, situation, or act with the potential to cause harm in terms of human injury, ill health, property damage, environmental degradation, or a combination of these.

Examples of Hazards:

- Toxic chemicals
- Sharp blades
- Electrical current
- Extreme temperatures
- Moving machinery



Table I.3: Hazard Classification System

Category	Description	Examples
Physical	Hazards arising from physical agents or conditions	Noise, radiation, extreme temperatures, vibration, lighting
Chemical	Hazards from chemical substances	Toxic, corrosive, flammable, or reactive substances
Biological	Hazards from living organisms	Bacteria, viruses, mold, insect bites, blood-borne pathogens
Ergonomic	Hazards related to work design	Poor posture, manual handling, repetitive motion, improperly adjusted workstations
Psychosocial	Hazards related to work environment	Stress, harassment, bullying, excessive workload, lack of control
Electrical	Hazards from electrical energy	Direct or indirect contact with live parts, electrical fires
Fire/Explosion	Hazards from combustion	Flammable materials, ignition sources, oxygen presence

1.4.2. Core Concept 2: Risk

Definition: **Risk** is defined as the combination of the likelihood (probability) and the severity (consequence) of harm arising from exposure to a hazard.

Fundamental Equation:

$$\boxed{\text{RISK} = \text{HAZARD} \times \text{EXPOSURE}}$$

Where:

- **HAZARD** represents the inherent potential to cause harm;
- **EXPOSURE** represents the frequency and duration of contact with the hazard.

Table I.4: Illustrative Risk Examples

Scenario	Hazard	Exposure	Risk Level
Low Risk	Flammable chemical	Stored in small quantity in appropriate container; rarely handled by trained personnel	LOW
High Risk	Same flammable product	Spilled in large quantity in workshop with uncontrolled conditions	HIGH

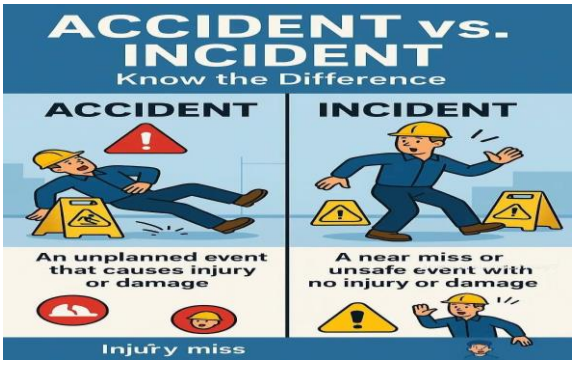
1.4.3. Core Concept 3: Accident, Incident, and Damage

Accident: An **accident** is defined as an unexpected, unplanned event arising from work activity that results in bodily injury, ill health, or material damage.

Example: A worker slips on an oily floor and fractures a bone.

Incident (Near-Miss): An **incident** (also known as a near-miss) is an event that, while not causing damage or injury, had the potential to do so. Incidents serve as critical warning signals and opportunities for preventive action.

Example: A falling object narrowly misses a worker.



What is the difference between accidents, incident, and hazard in workplace safety?

Damage: **Damage** refers to the negative consequence resulting from an accident, which may include:

- Bodily injury or ill health
- Occupational disease
- Material or property damage
- Environmental degradation

1.5. Practical Application Exercise

Exercise 1: Hazard Identification and Classification

Context: In an industrial setting, various workplace hazards may be present. The ability to identify and correctly classify these hazards is a fundamental skill in HSE management.

-Slippery floors / Vibration from equipment / Fungi and mold in ventilation / Unguarded machinery / Blood or other bodily fluids / Poor air quality / Excessive workload / Working from heights / Noise exposure / Insect bites / Asbestos exposure / Poor posture / Bacteria and viruses / Radiation exposure / Hazardous waste / Cleaning products and paints / Carbon monoxide exposure / Wood or cement dust / Welding or exhaust fumes / Improperly adjusted workstations / Frequent lifting / Repetitive motion / Workplace violence / Harassment and bullying / Lack of control over work / Electrical hazards / Water pollution / Extreme temperatures

Instructions:

1. Review the list of workplace situations provided below;
2. Identify the hazard present in each situation;
3. Classify each hazard according to its type;
4. Justify your classification.

Solution Key

Item	Situation	Hazard Identified	Classification	Justification
1	Slippery floors	Slippery surface	Physical	Condition causing loss of balance
2	Vibration from equipment	Vibration	Physical	Physical agent affecting the body

3	Fungi and mold in ventilation	Fungi/Mold	Biological	Living organism hazard
4	Unguarded machinery	Moving parts	Physical/Mechanical	Mechanical energy source
5	Blood or other bodily fluids	Biological fluids	Biological	Potential pathogen exposure
6	Poor air quality	Air contaminants	Chemical/Environmental	Chemical or particulate exposure
7	Excessive workload	Work overload	Psychosocial	Organizational stress factor
8	Working from heights	Fall potential	Physical	Gravity-related hazard
9	Noise exposure	Excessive noise	Physical	Physical energy hazard
10	Insect bites	Insects	Biological	Living organism hazard
11	Asbestos exposure	Asbestos fibers	Chemical	Carcinogenic substance
12	Poor posture	Poor ergonomics	Ergonomic	Postural stress
13	Bacteria and viruses	Pathogens	Biological	Infectious agents
14	Radiation exposure	Radiation	Physical	Ionizing/non-ionizing energy
15	Hazardous waste	Toxic materials	Chemical/Environmental	Chemical contamination source
16	Cleaning products, paints	Chemical substances	Chemical	Toxic/corrosive/flammable materials

17	Carbon monoxide	Carbon monoxide gas	Chemical	Toxic gas
18	Wood/cement dust	Particulates	Chemical	Respiratory hazards
19	Welding/exhaust fumes	Fumes	Chemical	Toxic inhalation hazards
20	Improperly adjusted workstations	Poor ergonomics	Ergonomic	Physical strain
21	Frequent lifting	Manual handling	Ergonomic	Physical overload
22	Repetitive motion	Repetitive strain	Ergonomic	Musculoskeletal stress
23	Workplace violence	Violence	Psychosocial	Social threat
24	Harassment and bullying	Psychological abuse	Psychosocial	Mental stressor
25	Lack of control over work	Powerlessness	Psychosocial	Psychological stressor
26	Electrical hazards	Electrical current	Electrical	Electrocution risk
27	Water pollution	Contaminants	Environmental	Ecological damage
28	Extreme temperatures	Temperature extremes	Physical	Thermal stress

SECTION 2: Prevention Stakeholders and Safety Performance Indicators

2. Prevention Stakeholders and Safety Performance Indicators

2.1. Learning Objectives

At the end of this section, the learner will be able to:

- Identify the internal and external stakeholders involved in workplace safety;
- Define the roles and responsibilities of each prevention actor;
- Explain the importance of safety performance indicators in HSE management;
- Calculate and interpret Frequency Rate, Severity Rate, Average Time Lost, and Frequency-Severity Index;
- Evaluate organizational HSE performance using quantitative indicators.

2.2. Prevention Stakeholders

2.2.1. Introduction: Shared but Differentiated Responsibility

Safety is everyone's responsibility; however, the level and nature of this responsibility vary according to organizational role and legal obligations. A comprehensive safety system requires the effective collaboration of both **internal stakeholders** (within the organization) and **external stakeholders** (outside the organization).

2.2.2. Internal Prevention Stakeholders

Table I.5: Internal Stakeholders and Their Responsibilities

Stakeholder	Role	Key Responsibilities
Employer	Legal responsibility holder	Assess risks; implement preventive measures; develop Single Risk Assessment Document; allocate resources
Employee	Frontline safety actor	Follow safety procedures; report hazards; exercise right to refuse unsafe work; participate in training
HSE Committee	Employee representative body	Represent employees; consult on projects; analyze risks and accidents; propose preventive measures
Occupational Physician	Medical advisor	Advise employer and employees; provide medical surveillance; contribute to ergonomic assessments

2.2.3. External Prevention Stakeholders

Table I.6: External Stakeholders and Their Functions

Stakeholder	Function	Key Activities
Ministry of Labor	Legislation and policy	Develop labor legislation; formulate safety policies; establish legal frameworks
Labor Inspectorate	Enforcement and control	Monitor compliance; exercise power to sanction; conduct inspections and investigations
Social Security	Insurance and prevention	Provide coverage for occupational accidents/diseases; manage compensation; support prevention programs

2.3. Safety Performance Indicators

2.3.1. Why Measure Safety Performance?

Principle: *"What gets measured gets managed."*

The measurement of safety performance through quantitative indicators serves three primary objectives:

1. **Track HSE performance trends** over time to identify improvements or deterioration;
2. **Identify action priorities** by highlighting areas requiring intervention;
3. **Benchmark** against industry standards and comparable organizations.

2.3.2. Indicator 1: Frequency Rate (FR)

Definition: The **Frequency Rate** measures how frequently lost-time injuries occur within a defined period.

Formula:

$$FR = \frac{\text{Number of Lost-Time Injuries} \times 1{,}000{,}000}{\text{Total Hours Worked}}$$

***Interpretation*:** The Frequency Rate represents the number of accidents per **one million hours worked**.

Example: 5 lost-time injuries, 500,000 hours worked → **FR =** $(5 \times 1{,}000{,}000)/500{,}000 = 10$

2.3.3. Indicator 2: Severity Rate (SR)

Definition: The **Severity Rate** measures the average severity of accidents based on the number of working days lost.

Formula:

$$SR = \frac{\text{Total Lost Days} \times 1{,}000}{\text{Total Hours Worked}}$$

Interpretation: The Severity Rate represents the number of lost days per **thousand hours worked**.

Example: 200 lost days, 500,000 hours worked → **SR** = $(200 \times 1{,}000)/500{,}000 = 0.4$

2.3.4. Indicator 3: Average Time Lost (ATL)

Definition: The **Average Time Lost** measures the average duration of absence per accident.

Formula:

$$ATL = \frac{\text{Total Lost Days}}{\text{Number of Lost-Time Injuries}}$$

***Interpretation*:** The Average Time Lost indicates the average severity of an accident in terms of working days lost.

Example: 200 lost days for 5 accidents → **ATL** = $200/5 = 40$ days/accident

2.3.5. Indicator 4: Frequency-Severity Index (FSI)

Definition: The **Frequency-Severity Index** combines the frequency and severity of accidents into a single value to evaluate overall safety performance.

Formula:

$$FSI = \frac{FR \times SR}{1{,}000}$$

***Interpretation*:** Higher values indicate more frequent or more severe accidents; lower values reflect better safety conditions.

Example: FR = 5, SR = 200 → **FSI** = $(5 \times 200)/1{,}000 = 1.0$

2.4. Practical Application Exercise

Exercise 1: Safety Indicators Calculation

Context: Company "X" has compiled its annual HSE data for 2023.

Parameter	Value
Average workforce	120 employees
Hours worked	240,000 hours
Lost-time injuries	4 injuries
Total lost days	125 days

***Instructions*:**

1. Calculate FR, SR, ATL, and FSI;
2. Interpret each result;
3. Provide an overall evaluation of Company "X's" HSE performance.

Solution Key

Performance Indicators Calculation

Indicator	Formula	Calculation	Result
FR	(N × 1,000,000) / Hours	(4 × 1,000,000) / 240,000	16.67
SR	(Lost Days × 1,000) / Hours	(125 × 1,000) / 240,000	0.52
ATL	Lost Days / N	125 / 4	31.25 days
FSI	(FR × SR) / 1,000	(16.67 × 0.52) / 1,000	0.0087

Performance Analysis Summary

Indicator	Value	Interpretation	Assessment
FR	16.67	Moderate number of accidents per million hours worked	Acceptable
SR	0.52	Low severity of accidents	Good
ATL	31.25 days	Average absence of approximately one month per accident	Moderate impact
FSI	0.0087	Combined measure of frequency and severity	Acceptable

Overall Conclusion: Company X demonstrates an **acceptable HSE performance**: the accident rate remains within a reasonable level, and accident severity is relatively limited. It is recommended to maintain and strengthen prevention programs, enhance awareness campaigns, and continue monitoring.

SECTION 3: Risk Analysis Methodology

3. Risk Analysis Methodology

3.1. Learning Objectives

At the end of this section, the learner will be able to:

- Define risk analysis and explain its importance in accident prevention;
- Identify hazards using various methods and tools;
- Assess risks using the Risk Assessment Matrix;
- Determine appropriate control measures using the SIRP hierarchy;
- Document risk analysis findings effectively;
- Apply risk analysis methodology to real-world scenarios.

3.2. What is Risk Analysis?

3.2.1. Definition

Risk Analysis is defined as a structured, proactive process that aims to identify hazards and estimate risks in order to implement preventive measures **before** accidents occur. It is an iterative process following the cycle:

ASSESSMENT → ACTION → REASSESSMENT → CONTINUOUS IMPROVEMENT

3.2.2. Why Risk Analysis Matters

Table I.7: Importance and Benefits of Risk Analysis

Benefit	Explanation
Accident Prevention	Identifies hazards before they cause harm
Cost Reduction	Prevents costly accidents and operational downtime
Safety Culture	Promotes proactive safety thinking
Regulatory Compliance	Fulfills legal obligations
Resource Optimization	Enables targeted investment in controls



Figure I.3: The Risk Analysis Cycle Applied to Noise Control

3.3. Step 1: Hazard Identification

3.3.1. Methods and Tools for Hazard Identification

Table I.8: Hazard Identification Methods

Method	Description	Application
Direct Observation	Workplace walkthroughs and visual inspections	Identifying visible hazards
Safety Inspections	Systematic inspections using checklists	Standardized hazard detection
Employee Interviews	Talking to experienced workers	Capturing tacit knowledge
Job Safety Analysis (JSA)	Step-by-step task analysis	Identifying hazards in specific procedures
Safety Data Sheets (SDS)	Review of chemical information	Understanding chemical hazards
Incident Report Analysis	Learning from past events	Identifying recurring patterns

Interactive Activity:

Scenario 1:* *Workplace Safety - Slips, Trips & Falls

Hazard Observed	Type	Description
Wet or slippery surfaces	Physical	Condition causing loss of balance
Cables or tools on floor	Physical	Trip hazards
Unsafe ladders or platforms	Physical	Fall from height risk
Poor lighting or disorganized walkways	Physical	Reduced visibility
Uneven surfaces	Physical	Trip hazard

Preventive Measures:

- Keep floors clean and dry;
- Organize the workplace and remove obstacles;
- Use warning signs such as "Wet Floor";
- Wear non-slip safety shoes.

Scenario 2:* *Ladder Safety Training

Hazard Observed	Type	Description
Unstable ladder placement	Physical	Fall from height risk
Climbing without three points of contact	Physical	Loss of balance
Carrying tools while climbing	Physical	Affects balance
Damaged or inappropriate ladder	Physical	Equipment failure
Ladder on uneven surface	Physical	Instability

Preventive Measures:

- Ensure the ladder is firmly placed on a stable and dry surface;
- Inspect the ladder before use;
- Maintain three points of contact (two hands and one foot, or two feet and one hand);
- Do not exceed the safe height limit of the ladder;
- Wear slip-resistant safety shoes.

3.4. Step 2: Risk Assessment

3.4.1. The Two Assessment Criteria

Table I.9: Severity Scale

Level	Description	Examples
Negligible (1)	First aid injury	Minor cuts, bruises
Minor (2)	Medical treatment required	Stitches, small fractures
Moderate (3)	Lost-time injury	Serious injury requiring absence
Major (4)	Permanent disability	Amputation, hearing loss
Catastrophic (5)	Single or multiple fatalities	Deaths, permanent total disability

Table I.10: Probability Scale

Level	Description	Likelihood
Very Unlikely (1)	Exceptional circumstances	$< 1\%$
Unlikely (2)	Remote possibility	1-10%
Possible (3)	Might occur occasionally	10-30%
Likely (4)	Probably will occur	30-70%
Almost Certain (5)	Frequent occurrence	$> 70\%$

3.4.2. Risk Assessment Matrix

Table I.11: Risk Assessment Matrix

Probability / Severity	**Negligible (1)**	**Minor (2)**	**Moderate (3)**	**Major (4)**	**Catastrophic (5)**
Almost Certain (5)	Medium (5)	High (10)	Very High (15)	Very High (20)	Extreme (25)
Likely (4)	Medium (4)	Medium (8)	High (12)	Very High (16)	Very High (20)
Possible (3)	Low (3)	Medium (6)	Medium (9)	High (12)	Very High (15)
Unlikely (2)	Low (2)	Low (4)	Medium (6)	Medium (8)	High (10)
Very Unlikely (1)	Negligible (1)	Low (2)	Low (3)	Medium (4)	Medium (5)

Risk Assessment Formula:

$$\text{RISK LEVEL} = \text{SEVERITY} \times \text{PROBABILITY}$$

Table I.12: Risk level Legend

Risk Level	Score Range	Action Required
EXTREME / VERY HIGH	15-25	Immediate corrective action required. Activity should stop until risk is controlled.
HIGH	10-12	Short-term corrective action required. Management attention needed.
MEDIUM	4-9	Requires attention and monitoring. Schedule improvements.
LOW / NEGLIGIBLE	1-3	Acceptable risk. Routine monitoring sufficient.

3.5. Step 3: Determine Control Measures

3.5.1. Hierarchy of Controls (SIRP Principle)



Figure I.4: Hierarchy of Controls (SIRP Principle)

3.5.2. Examples of SIRP Hierarchy Application

The following examples illustrate the application of the SIRP hierarchy (Substitution, Isolation, Redesign/Reorganize, and Personal Protective Equipment) to common workplace hazards:

Table I.13: SIRP Hierarchy Application Examples

Hazard	S - Substitution	I - Isolation	R - Redesign/Reorganize	P - PPE
Flammable liquids near electrical panels	Replace with non-flammable alternatives	Install fire-resistant barriers	Relocate storage; implement electrical safety procedures	Provide fire-resistant clothing and gloves
Poor ventilation	Use less volatile chemicals	Install explosion-proof ventilation	Redesign layout; establish maintenance schedule	Provide respiratory protection
No spill containment	Replace liquids with solid forms	Install containment bunds and drip trays	Implement spill response procedures; train staff	Provide chemical-resistant suits and gloves
Inadequate labeling	Use pre-labeled containers	Implement standardized labeling system	Redesign storage; train on GHS; conduct audits	Ensure label readability

3.6. Risk Analysis Documentation

3.6.1. Essential Elements of Risk Analysis Documentation

Proper documentation is a critical component of the risk analysis process. It ensures traceability, facilitates communication, and supports continuous improvement. The following table presents the essential elements that must be included in any risk analysis document.

Table I.14: Essential Elements of Risk Analysis Documentation

Element	Description	Example
Hazard Description	Clear and specific identification	"Flammable solvents stored adjacent to electrical distribution panel"
Risk Assessment	Severity, Probability, Risk Level	Severity: 4, Probability: 3, Risk Level: 12 (High)
Control Measures	Proposed actions using SIRP hierarchy	"Relocate solvents to flammable storage cabinet (Isolation)"
Responsible Person	Who will implement the control	"Maintenance Supervisor"
Timeline	Implementation deadline	"Complete within 30 days"
Review Date	When to reassess effectiveness	"60 days after implementation"

SECTION 4: Root Cause Analysis Methods

4. Root Cause Analysis Methods

4.1. Learning Objectives

At the end of this section, the learner will be able to:

- Explain the purpose and importance of root cause analysis in accident prevention;
- Apply the 5 Whys technique to identify root causes;
- Construct and interpret Cause and Effect (Fishbone/Ishikawa) diagrams;
- Differentiate between accident and incident analysis;
- Develop corrective actions using SMART criteria;
- Document root cause analysis findings effectively.

4.2. Introduction to Accident Analysis

4.2.1. Why Analyze Accidents?

Accident analysis serves three fundamental purposes:

1. **Understand why accidents happen**, not who is responsible;
2. **Prevent recurrence** by addressing root causes;
3. **Improve safety systems and procedures** at an organizational level.

Table I.15: Accident vs. Incident Distinction

Term	Definition	Key Characteristic
Accident	Event resulting in injury, illness, or damage	**Actual harm occurred**
Incident (Near-Miss)	Event with potential for harm but no damage occurred	**Warning signal**, no harm occurred

4.3. What is Root Cause Analysis?

4.3.1. Definition

Root Cause Analysis (RCA) is defined as a structured method used to analyze serious adverse events in order to identify underlying root causes and develop corrective actions that prevent recurrence.

4.3.2. Key Principles of Root Cause Analysis



Figure I.5: Root Cause Analysis

Table I.16: Fundamental Principles of RCA

Principle	Description
Systematic Approach	Follows a structured methodology, not ad hoc investigation
Systems Focus	Focuses on systems and processes, not individual blame
Depth Analysis	Digs beyond immediate causes to identify underlying factors
Permanent Solutions	Aims to eliminate root causes, not just treat symptoms

4.3.3. Common RCA Methods

Table I.17: Comparison of RCA Methods

Method	Description	Best Used For	Complexity
5 Whys	Simple questioning method drilling down to root cause	Simple to moderately complex problems	Low
Cause and Effect Diagram (Fishbone/Ishikawa)	Visual tool organizing potential causes into categories	Complex problems with multiple contributing factors	Medium
Fault Tree Analysis (FTA)	Deductive, top-down approach using Boolean logic	System failures with multiple components	High

4.4. The 5 Whys Technique

4.4.1. Demonstration

To illustrate the practical application of the 5 Whys Technique, the following case study is presented:

***Scenario*:** *A worker slips and falls in the workshop.*



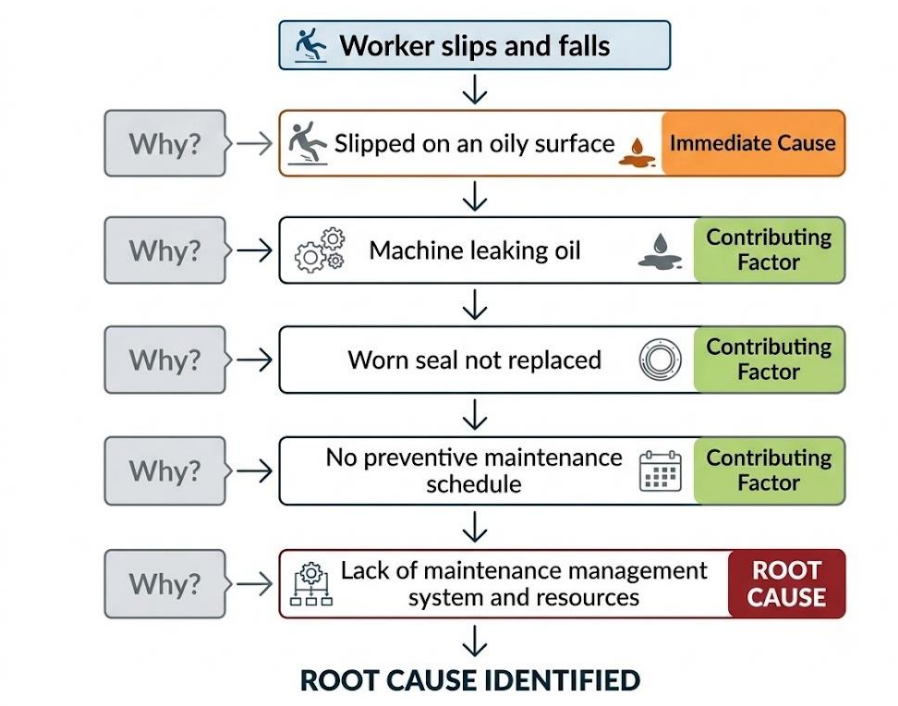


Figure I.6: The 5 Whys Process

Proposed Solution:

Implement a Preventive Maintenance Management System (CMMS).

4.4.2. Interactive Activity: 5 Whys Practice

Scenario: A chemical spill occurred during transfer operations, exposing two workers to hazardous vapors.

Table I.18: Application of the 5 Whys Technique

Level	Question	Answer
1st Why	Why did the spill occur?	Transfer hose burst due to wear and tear and not being replaced on time
2nd Why	Why weren't containment measures effective?	Containment tray was full and not emptied, with no clear spill response procedures
3rd Why	Why were workers exposed to hazardous vapors?	They weren't wearing appropriate respiratory protection and weren't trained on vapor hazards
4th Why	Why weren't safety controls in place?	No updated risk assessment and reliance on informal procedures
5th Why	Why did these system gaps persist?	**Root Cause:** Lack of integrated safety management system and insufficient safety resource allocation

Root Cause Identification:

Visible Problem: **Chemical Spill → Root Cause: Absence of safety culture**

→ Solution: Comprehensive safety management system

4.5. Cause and Effect Diagram (Fishbone/Ishikawa)

4.5.1. Definition and structure

What is this diagram?

It is a visual analysis tool resembling a fishbone, used to identify all potential causes of a specific problem. (Cause-and-Effect Diagram)

Main Components:

Table I.19: Fishbone Diagram Components

Component	Description
Fish Head (Right)	The main problem or effect to be analyzed
Fish Bones (Main Branches)	Major cause categories (typically the 6Ms)
Small Bones (Sub-Branches)	Specific causes within each category



How to use this diagram?

- Define the problem clearly in the fish head
- Gather a work team from all specialties
- Suggest causes under each category
- Analyze the causes and identify the most impactful ones
- Apply appropriate solutions

4.5.2. The 6 Ms Categories

Table I.20: The 6Ms in Cause and Effect Analysis

Category	Description	Examples
People(Man)	Human factors	Training, experience, supervision, skills, attitudes
Methods	Processes and procedures	Work procedures, communication, planning, safety protocols
Materials	Inputs to the process	Quality, storage, handling, labeling, specifications
Machines	Equipment and tools	Maintenance, age, design, condition, guarding
Environment	Working conditions	Lighting, temperature, layout, cleanliness, ergonomics
Measurement	Monitoring and control	Inspection, monitoring, calibration, data collection

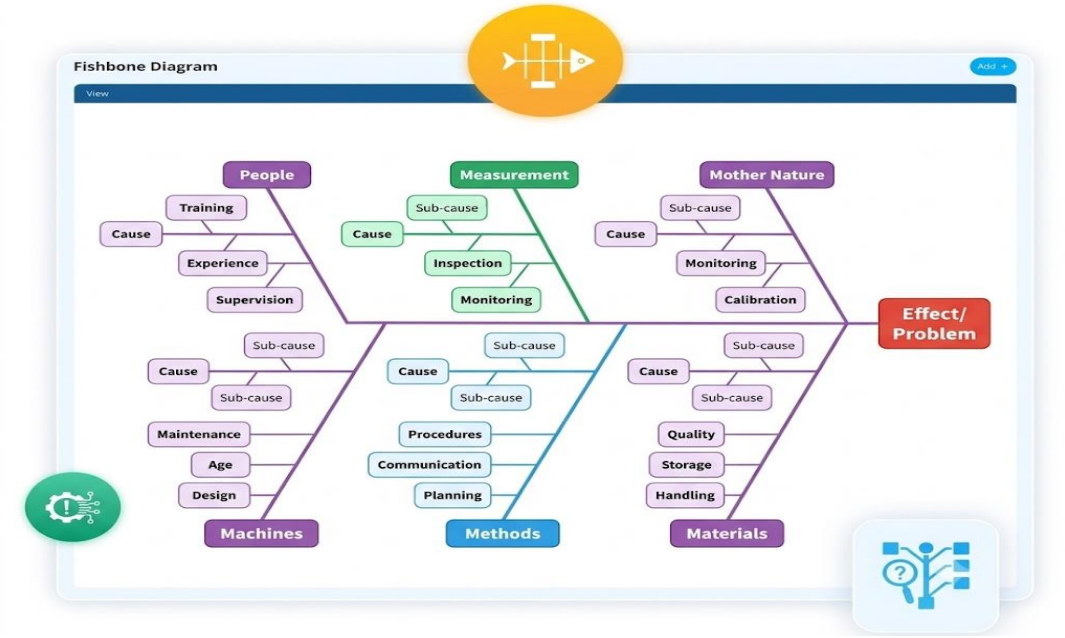


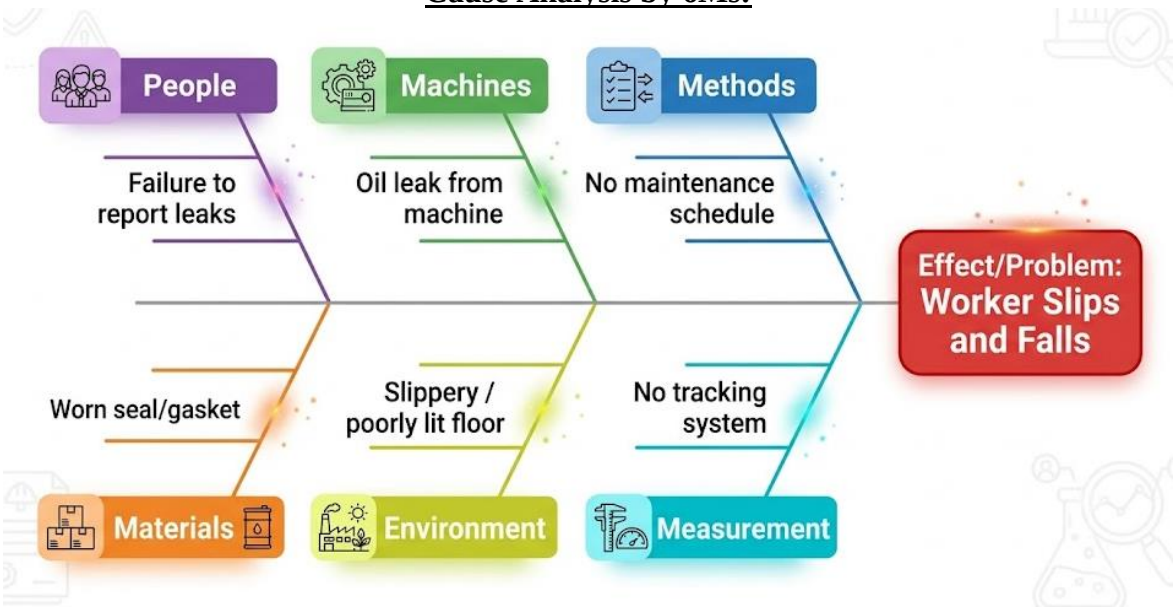
Figure I.7: Fishbone Diagram

4.5.3. Application: Repeated Slipping Incidents Diagram

Problem: A worker slipped and fell on an oily surface.

Fishbone Diagram:

Cause Analysis by 6Ms:



Category	Cause
Man	Poor reporting of leaks, insufficient training, weak supervision
Machine	Oil leak from machine, worn seal/gasket
Material	Oil spilled on floor, no absorbent materials available
Method	No preventive maintenance schedule, unclear work procedures
Measurement	No system to track maintenance performance or failures
Environment	Poor lighting, slippery non-slip floor

Proposed Solution:

Implement a Preventive Maintenance System (PMS) that directly addresses the root cause: *No maintenance management system and resources.*

4.6. RCA Case Study: Conveyor Accident

4.6.1. Scenario

A maintenance worker was severely injured while repairing a conveyor system.

Initial Facts:

- Worker bypassed safety interlock;
- Machine started unexpectedly;
- No lockout/tagout procedure followed;
- Inadequate supervision.

Investigation Findings:

- Multiple system failures identified;
- Organizational and cultural issues;
- Training deficiencies;
- Equipment design flaws.

4.6.2. Group Activity: RCA Diagram Construction

Task: Create a Cause and Effect Diagram for the conveyor accident.

Table I.21: Categories to Consider

Category	Analysis Questions
People	Training, competence, supervision, experience
Methods	Procedures, work permits, communication, authorization
Machines	Design, maintenance, safety features, interlocks
Environment	Lighting, noise, workspace, accessibility
Management	Policies, resources, safety culture, leadership

4.7. From Analysis to Action

4.7.1. Turning Findings into Prevention

Table I.22: Types of Actions:

Action Type	Description	Examples
Immediate Actions	Address urgent safety issues	Stop activity; temporary guards; warnings
Corrective Actions	Fix identified root causes	Repair equipment; update procedures; provide training
Preventive Actions	Systemic improvements	Change management systems; enhance safety culture; redesign processes

4.7.2. Effective Corrective Actions

SMART Criteria for Actions:

All corrective actions must meet the SMART criteria to ensure they are practical and effective.

Table I.23: SMART Criteria Explained

Criterion	Description	Example
Specific	Clear and precise description	"Train all 15 maintenance staff on new LOTO procedure"
Measurable	Quantifiable results	"100% of staff must pass competency test"
Achievable	Realistic and feasible	"Training sessions scheduled for 3 days"
Relevant	Addresses root cause	"Procedure addresses bypassing interlocks"
Time-bound	Clear deadline	"Complete by end of month"

Table I.24: Effective vs. Ineffective Actions Comparison

Effective Action	Ineffective Action
"Train all maintenance staff on updated LOTO procedures by 31 March 2027"	"Improve safety training"
"Replace all worn conveyor belts by 15 February 2027"	"Maintain equipment regularly"
"Conduct daily safety inspections of all ladders"	"Be more careful"

Key Takeaway:

Effective actions are **specific, measurable, and time-bound**, while ineffective actions are vague and unverifiable. Always use **SMART** criteria when proposing corrective actions.

4.8. RCA Documentation

Table I.25: Essential Report Elements

Element	Description
Executive Summary	Overview of incident and findings
Incident Description	Detailed account of what happened
Timeline	Chronological sequence of events
Investigation Methodology	How the investigation was conducted
Causal Analysis Findings	Root causes identified
Recommended Actions	Specific corrective and preventive measures
Responsibility and Timelines	Who will implement what and when
Follow-up and Verification Plan	How effectiveness will be measured

4.9. Common RCA Pitfalls

Table I.26: Mistakes to Avoid in RCA

Pitfall	Description	Consequence
Stopping at Symptoms	Not digging deep enough to find root causes	Ineffective solutions
Blaming Individuals	Focusing on who made the error	Missing systemic factors; creating blame culture
Rushing to Solutions	Premature conclusion without thorough analysis	Addressing wrong problems
Failing to Verify	Not confirming root causes with evidence	False conclusions
Excluding Frontline Workers	Not involving those closest to the work	Missing critical knowledge
Ignoring Organizational Factors	Overlooking culture and management influences	Incomplete analysis

SECTION 5: Risk Families and Integrated Case Study

5. Risk Families and Integrated Case Study

5.1. Learning Objectives

At the end of this section, the learner will be able to:

- Classify risks and apply risk assessment
- Develop control plans using the SIRP hierarchy
- Integrate concepts into a holistic approach.

5.2. What are Risk Families?

5.2.1. Definition

Risk families are classifications of risks into cohesive groups based on the nature of the harmful energy or hazard source that generates them.

5.2.2. Benefits of Risk Family Classification

Table I.27: Benefits of Risk Classification

Benefit	Explanation
Facilitates Identification	Provides a structured framework for recognizing hazards
Improves Management	Enables targeted prevention strategies for each risk type
Enhances Safety Culture	Develops systematic thinking about workplace risks
Supports Training	Allows focused training on specific risk categories

5.3. Detailed Analysis of Each Risk Family

5.3.1. Mechanical Risk Family

Aspect	Description
Source	Mechanical energy, moving parts
Potential Effects	Cutting, wounding, crushing, entanglement, impact
Examples	Saws, fans, pulleys, conveyor belts, rotating machinery, presses
Prevention	Machine guarding, lockout/tagout, safe work procedures



5.3.2. Electrical Risk Family

Aspect	Description
Source	Electric current (direct or indirect contact)
Potential Effects	Electrocution, burns (Arc Flash), fires, explosions
Causes	Contact with live parts, damaged insulation, improper grounding
Prevention	Insulation, grounding, circuit breakers, lockout/tagout



Table I.28: Electrical Hazard Effects

Effect	Description	Severity
Electrocution	Fatal electric shock	Catastrophic
Arc Flash Burns	Thermal burns from electrical arc	Major
Electrical Fires	Ignition due to electrical faults	Moderate to Major
Secondary Effects	Falls resulting from shock	Varies

5.3.3. Chemical Risk Family

Aspect	Description
Exposure Routes	Inhalation, skin contact, ingestion, injection
Potential Effects	Poisoning, chemical burns, skin or respiratory allergies, organ damage
Identification Tool	Globally Harmonized System (GHS) pictograms
Prevention	Substitution, ventilation, PPE, safe storage, labeling

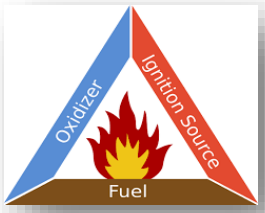




5.3.4. Fire & Explosion Risk Family

Fire Triangle Theory

Element	Prevention Strategy
Oxygen	Inerting, oxygen reduction
Fuel	Safe storage, substitution, housekeeping
Ignition Source	Eliminate sources of ignition, grounding, bonding



Prevention Principle: Removing any one side of the triangle prevents combustion.

5.3.5. Fall Risk Family

Table I.29: Types of Fall Risks

Type	Causes	Preventive Measures
Same-Level Falls	Slippery floors, congested walkways, poor lighting, obstacles	Housekeeping, anti-slip surfaces, warning signs, non-slip shoes
Falls from Height	Working on roofs, unstable scaffolds, ladders, unprotected edges	Guardrails, fall arrest systems, safe ladder use, training



5.3.6. Ergonomics Risk Family

Aspect	Description
Effects	Musculoskeletal disorders, back injuries, repetitive strain injuries
Causes	Manual handling of heavy loads, incorrect body postures, repetitive movements
Example	A person lifting a heavy box with incorrect posture
Prevention	Ergonomic design, mechanical aids, job rotation, training

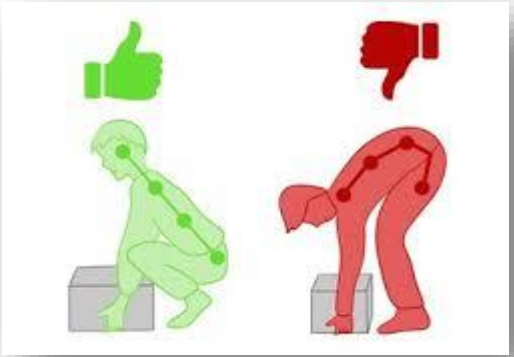


Table I.30: Ergonomic Risk Factors

Risk Factor	Description	Potential Disorder
Heavy Lifting	Manual handling of excessive loads	Back injury, herniated disc
Awkward Posture	Bending, twisting, reaching	Musculoskeletal strain
Repetitive Motion	Repeating same movements	Carpal tunnel syndrome, tendonitis
Prolonged Standing	Extended periods on feet	Leg and foot disorders
Vibration	Operating vibrating tools	Hand-arm vibration syndrome

5.3.7. Psychosocial Risk Family

Aspect	Description
Source	Work environment and organizational culture
Manifestations	Work-related stress, burnout, harassment, bullying
Consequences	Deteriorating mental health, decreased productivity, increased absenteeism
Prevention	Workload management, supportive culture, clear communication, employee assistance



5.4. Integrated Case Study: HSE Consultant Simulation

Scenario

The company "**FabricPlus**" hires you as HSE Consultants to conduct a preliminary risk assessment in their packaging workshop.

Task: Conduct a comprehensive risk assessment including:

1. Hazard identification and classification
2. Risk assessment using the Risk Matrix
3. Prevention proposals using the SIRP hierarchy

6. Conclusion

This chapter laid the foundation for understanding Health, Safety, and Environment (HSE) management. We explored the essential definitions of Hazard, Risk, Accident, Incident, and Damage, and saw how these concepts connect throughout the safety lifecycle. We also examined how major disasters have shaped modern HSE practices, reinforcing the need for continual learning, prevention, and improvement.

We also highlighted the three interdependent pillars of an HSE management system Policy, Organization, and Planning & Implementation. Together, they support a strong safety culture and help organizations identify hazards, assess risks, and apply effective control measures in any context.

"Safety isn't just a slogan; it's a value that guides every decision, every action, and every innovation. It's the silent guardian of progress."

Chapter I Summary: From Hazard to Action

1. The Risk Management Pathway

Step	Action	Key Tools
1	Hazard Identification	Observation, Inspections, JSA, SDS, Incident Analysis
2	Risk Assessment	Severity × Probability = Risk Level (1-25)
3	Root Cause Analysis	5 Whys, Cause and Effect (Fishbone) Diagram
4	Control Measures	SIRP Hierarchy (Substitution → Isolation → Redesign → PPE)
5	Implementation & Monitoring	SMART Actions, Performance Indicators, Continuous Improvement

2. Key HSE Concepts

Concept	Definition
Hazard	Source or situation with potential to cause harm
Risk	Likelihood × Severity of harm from exposure to a hazard
Accident	Event resulting in injury, illness, or damage
Incident (Near-Miss)	Event with potential for harm but no damage occurred
HSE	Integrated system combining Health, Safety, and Environment

3. Prevention Stakeholders

Type	Key Actors	Functions
Internal	Employer, Employee, HSE Committee, Occupational Physician	Implementation, participation, representation, medical advice
External	Ministry of Labor, Labor Inspectorate, Social Security	Regulation, enforcement, insurance, policy development

4. Safety Performance Indicators

Indicator	Formula	Purpose
FR	(N × 1,000,000) / Hours	Measures accident frequency
SR	(Lost Days × 1,000) / Hours	Measures accident severity
ATL	Lost Days / N	Measures average absence duration
FSI	(FR × SR) / 1,000	Combined performance measure

5. The SIRP Hierarchy of Controls

Level	Control Type	Effectiveness
S	Substitution	Most Effective
I	Isolation	Very Effective
R	Redesign/Reorganize	Moderately Effective
P	Personal Protective Equipment	Least Effective

6. Risk Families

Mechanical, Electrical, Chemical, Fire & Explosion, Fall, Ergonomics, Psychosocial.

7. The HSE Philosophy

- **Safety is a Culture:** Embedded in organizational values, not just compliance
- **Continuous Improvement:** The safety journey never ends
- **Shared Responsibility:** Every stakeholder plays a role
- **Data-Driven Decision Making:** Indicators inform prevention strategies
- **Systems Thinking:** Focus on systemic causes, not individual blame

Final Message:

Risk management is an integrated system that starts with proper classification and ends with effective control plans.

Core Philosophy:

- From Theory to Application
- From Hazard to Action
- From Individual to System

Health, Safety and Environment (HSE)

In Industrial Installations

Chapter TWO: Occupational Health and Environmental Protection

Description: Protecting Worker Health and Ecosystems in Industrial Operations



Five-Session Roadmap

Section 1: Introduction to Occupational Health & Work-Related Diseases

Section 2: Industrial Hygiene & Environmental Monitoring

Section 3: Environmental Management in Industrial Facilities

Section 4: Industrial Waste Management

Section 5: Sustainability & Sustainable Development - Integrated Case Study

Chapter II: Occupational Health and Environmental Protection

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Introduction

This chapter is structured into five main sections. Each section addresses a key component of occupational health and environmental protection from work related diseases to sustainability and integrated case studies providing a progressive and comprehensive understanding of the subject.

SECTION 1: Introduction to Occupational Health and Work-Related Diseases

1. Introduction to Occupational Health and Work-Related Diseases

1.1. Learning Objectives

At the end of this section, the learner will be able to:

- Define occupational health and explain its importance in industrial settings;
- Distinguish between occupational safety and occupational health;
- Identify the exposure pathway from hazard to health effect;
- Recognize major occupational disease families;
- Understand the prevention hierarchy for health hazards;
- Explain the importance of medical surveillance programs.

1.2. Why Occupational Health Matters

1.2.1. The Silent Epidemic

Occupational diseases develop slowly over years of chronic exposure, unlike accidents which have immediate effects.

Table II.1: Key Distinction: Safety vs. Health

Aspect	Safety	Health
Focus	Preventing immediate accidents	Preventing chronic exposure
Examples	Falls, electrical shocks, fires/explosions, machinery injuries	Chemical poisoning, noise-induced hearing loss, respiratory diseases, ergonomic disorders
Temporal Nature	Immediate effects	Delayed effects (years)
Prevention Strategy	Short-term controls	Long-term monitoring and controls

Case Study: ***Asbestos-Related Diseases (Mesothelioma)***

Exposure to asbestos in the 1970s often manifests as disease after 30-40 years. This latency period makes occupational diseases particularly challenging to diagnose and prevent.

Key Difference:

Safety ➡ Preventing immediate accidents (e.g., falls, electrical shocks, fires/explosions, machinery injuries)

Health ➡ Preventing chronic exposure leading to long-term diseases (e.g., chemical poisoning, noise-induced hearing loss, respiratory diseases from dust, ergonomic disorders)

Important: Both safety and health are complementary for worker protection, but they require different prevention strategies due to the nature of their temporal impact.

1.3. Hazard vs. Health Effect: The Exposure Pathway

1.3.1. From Hazard to Health Effect

Understanding the pathway from hazard to health effect is essential for effective prevention. This pathway describes how a hazardous agent at the workplace travels through a transmission route to reach the worker's body and cause adverse health effects. Interrupting this pathway at any stage prevents the development of occupational diseases.

Basic Model:

SOURCE → PATHWAY → RECEIVER

Table II.2: Exposure Pathway Components

Component	Description	Examples
1. Source (The Hazardous Agent)	The origin of the hazard	• Chemical: Vapors, dusts, gases • Physical: Noise, radiation, heat • Biological: Bacteria, viruses
2. Pathway (Transmission Route)	How the hazard reaches the body	• Inhalation (lungs) • Dermal absorption (skin) • Ingestion (mouth) • Auditory (ear)
3. Receiver (The Body & Effect)	Target organs and health effects	• Target organs: Lungs, liver, kidneys, nervous system • Effects: Cellular damage, chronic diseases

Illustrative Examples:

Hazard	Pathway	Health Effect
Silica dust	**Inhalation**	**Pulmonary fibrosis (silicosis)**
Machine noise	**Auditory (ear)**	**Permanent hearing loss**
Chemical solvents	**Dermal absorption / Inhalation**	**Liver and kidney damage**

- **Prevention Principle:** Control the source or interrupt the pathway before the hazard reaches the worker.

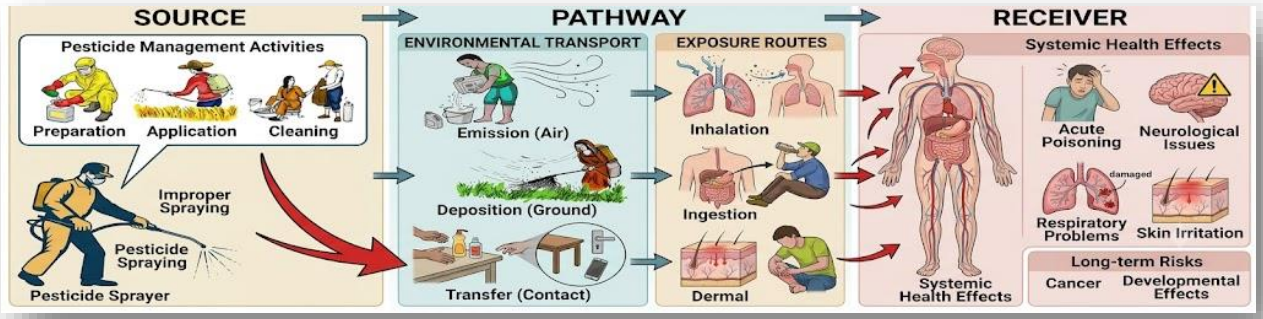


Figure II.1: The Exposure Pathway

1.4. Major Occupational Disease Families

Table II.3: Major Occupational Disease Families

Disease Family	Examples	Common Exposures
Respiratory Diseases	Pneumoconiosis (Silicosis, Asbestosis), Occupational Asthma	Dust, fibers, chemical vapors
Skin Diseases	Dermatitis, Chemical Burns	Solvents, acids, irritants
Musculoskeletal Disorders	Back injuries, Carpal Tunnel Syndrome	Repetitive motion, heavy lifting
Hearing Loss	Noise-Induced Hearing Loss (NIHL)	High noise levels
Poisoning & Systemic Effects	Heavy metal poisoning, Solvent effects on organs	Lead, mercury, organic solvents

1.5. Practical Application Exercise

Exercise 1: Disease Detective

Scenario:

A worker in a battery manufacturing plant reports chronic fatigue, abdominal pain, and mood changes.

Instructions:

Based on the scenario and your knowledge of battery manufacturing, answer the following questions:

1. What could be the hazardous exposure?
2. What is the likely disease?
3. What medical tests would you recommend?
4. Suggest preventive measures.

Hint: Think about battery components: Lead, Acid, Plastics

Exercise 1: Solution Key

Disease Detective – Solution:

Question	Answer
1. Likely Hazardous Exposure	Inhalation or ingestion of lead dust/fumes from battery components
2. Probable Disease	Chronic Lead Poisoning
3. Recommended Medical Tests	• Blood Lead Level (BLL) test • Zinc Protoporphyrin (ZPP) test • Kidney function tests • Complete Blood Count (CBC)
4. Preventive Measures	• **Substitution:** Use less toxic alternatives where possible • **Engineering Controls:** Efficient local and general ventilation systems • **Administrative Controls:** Reduced exposure time, job rotation, strict hygiene policies • **PPE:** Appropriate respirators (N95 or higher), gloves, goggles, protective aprons • Regular medical surveillance program for workers • Worker training on lead hazards and prevention methods

1.6. Prevention Hierarchy for Health Hazards

The prevention hierarchy consists of five levels, ranked from most effective to least effective:

1. Elimination

2. Substitution

3. Engineering Controls

4. Administrative Controls

5. PPE (Personal Protective Equipment)

Note: *The prevention hierarchy for health hazards follows the same principle as safety controls, with elimination being the most effective and PPE being the last line of defense.*

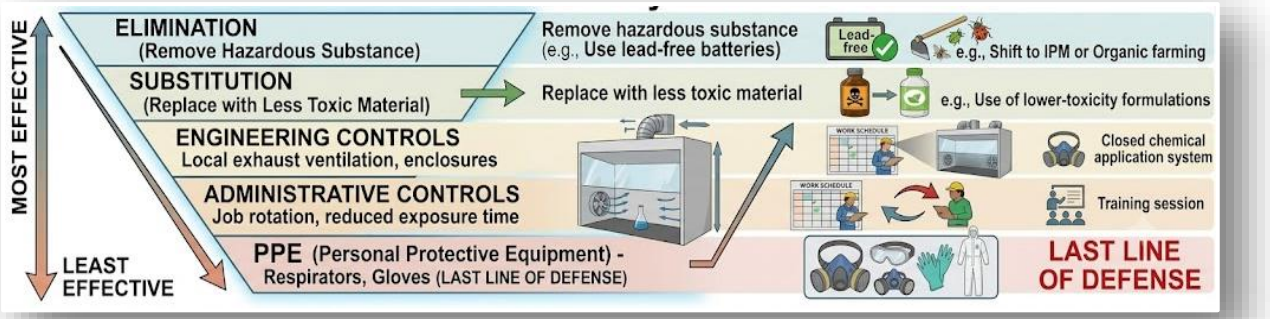


Figure II.1: Prevention and hierarchy for health hazards

1.7. Case Study: Silicosis in Construction

Scenario:

- Worker cutting concrete blocks for 10 years without proper protection
- Symptoms: Persistent cough, shortness of breath
- X-ray shows lung fibrosis

Silicosis Case Study Analysis

Question	Analysis
1. What went wrong?	Lack of proper respiratory protection, inadequate dust control, insufficient monitoring
2. Who failed? (Employer/Employee/System)	• **Employer:** Failure to provide PPE and implement controls • **Employee:** Failure to use available protection • **System:** Weak enforcement of safety regulations
3. How could this have been prevented?	• Proper dust control systems (water suppression, ventilation) • Mandatory use of approved respirators • Regular medical surveillance (lung function tests) • Worker training on silicosis risks

1.8. Medical Surveillance Programs

Table II.4: Medical Surveillance Program Components

Component	Description
Pre-employment Medical Exams	Baseline health assessment before starting work
Periodic Health Checkups	Regular monitoring for early detection of diseases
Biological Monitoring	Blood/Urine tests to measure exposure levels
Health Records Maintenance	Documentation of all medical data for trend analysis

- **Example:** Regular lung function tests for welders.

1.9. Legal Framework: Algerian Context

Table II.5: Algerian Legal Framework for Occupational Health

Element	Description
Law 90-11	Relating to prevention of occupational risks and compensation
Role of Occupational Physician	Médecin du Travail - responsible for worker health surveillance
Worker's Right	Right to know about health risks
Employer's Obligation	Obligation for medical surveillance

1.10. Key Performance Indicators for Health

Table II.6: Health Performance Indicators

Indicator	Description
Disease Incidence Rate	New cases per year
Absenteeism Rate due to Illness	Absence days related to occupational illness
Medical Surveillance Coverage Rate	Percentage of workers covered by medical programs
Biological Monitoring Compliance Rate	Percentage of workers completing required tests

SECTION 2: Industrial Hygiene and Environmental Monitoring

2. Industrial Hygiene and Environmental Monitoring

2.1. Learning Objectives

At the end of this section, the learner will be able to:

- Define industrial hygiene and its role in protecting worker health;
- Identify the four major environmental hazards (ANTE);
- Apply the Health Risk Assessment Cycle (RECCE);
- Calculate and interpret Time-Weighted Average (TWA);
- Understand Occupational Exposure Limits (OELs);
- Differentiate between personal monitoring, direct reading instruments, and biological monitoring.

2.2. What is Industrial Hygiene?

2.2.1. Definition:

Industrial Hygiene is the science and art dedicated to the recognition, evaluation, and control of environmental factors in the workplace that may lead to illness or discomfort.

Goal: Preventing occupational diseases by controlling chemical, physical, biological, and ergonomic hazards.

Table II.7: Occupational Safety vs. Industrial Hygiene

Aspect	*Occupational Safety*	*Industrial Hygiene*
Focus	Sudden energy release	Chronic exposure
Examples	Falls, fires, electrical shocks	Chemical poisoning, hearing loss, respiratory diseases
Temporal Nature	Immediate effects	Long-term/delayed effects

2.3. Four Major Environmental Hazards (ANTE)

Table II.8: Four Major Environmental Hazards (ANTE)

Category	Description	Examples
Chemical Hazards	Aerosols, gases, vapors, dusts, fumes, mists	Solvent vapors, metal fumes, acid mists
Physical Hazards	Noise, vibration, radiation, extreme temperatures	High noise levels, heat stress, radiation
Biological Hazards	Bacteria, viruses, fungi, toxic molds	Blood-borne pathogens, mold, bacteria
Ergonomic Hazards	Poor workstation design, repetitive motions	Awkward postures, heavy lifting, repetitive tasks

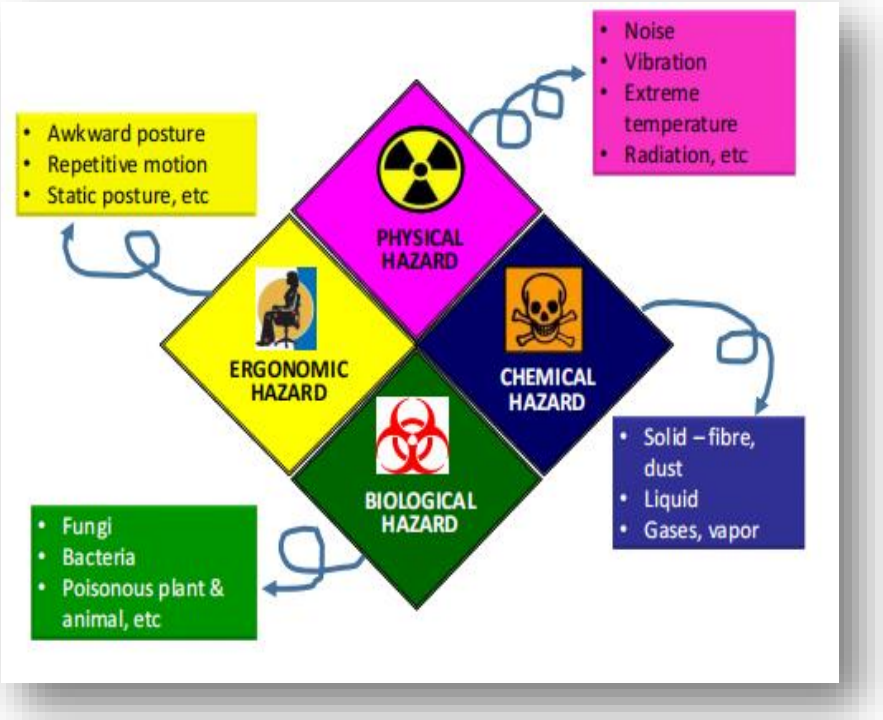


Figure II.3: Types of health hazards

2.4. Health Risk Assessment Cycle (RECCE)

The Health Risk Assessment Cycle consists of five sequential steps:

1. **Recognition:** What is the hazard? (e.g., solvent vapors)

2. **Evaluation:** What is the concentration? (measuring concentration and exposure time)
3. **Comparison:** Comparing results with Occupational Exposure Limits (OELs)
4. **Control:** Applying the prevention hierarchy (from elimination to PPE)
5. **Re-evaluation:** Periodically verifying control effectiveness

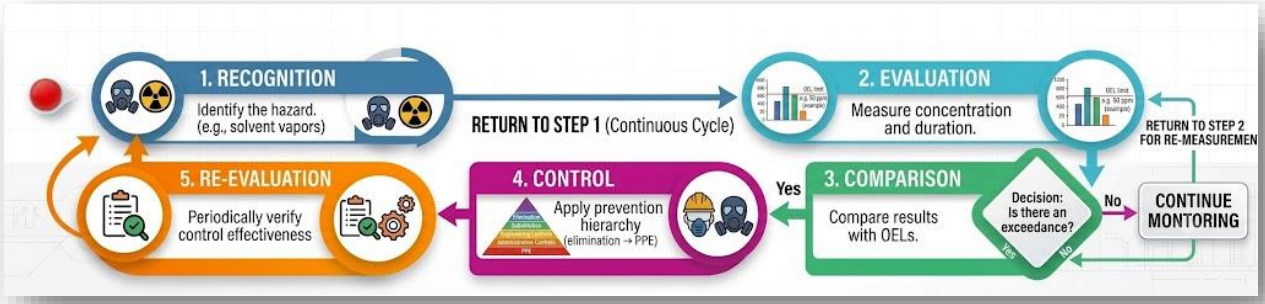


Figure II.4: Health Risk Assessment Cycle (RECCE)

2.5. Occupational Exposure Limits (OELs)

2.5.1. Definition

Occupational Exposure Limits (OELs) are permissible concentrations of a hazardous substance in workplace air at which most workers are not expected to suffer adverse health effects from repeated exposure.

2.5.2. Types of OELs

Table II.9: Types of Occupational Exposure Limits

Type	***Description***	***Duration***
TWA-PEL (Permissible Exposure Limit - Time-Weighted Average)	Average concentration over an 8-hour workday / 40-hour workweek	8 hours
STEL (Short-Term Exposure Limit)	15-minute average concentration that must not be exceeded	15 minutes
IDLH (Immediately Dangerous to Life or Health)	Concentration posing an immediate threat to life or health	Immediate

2.6. Monitoring and Assessment Tools

Personal Sampling (Most Accurate)	***Examples :*** Air sampling pump with filter cassettes, Worn on the worker's collar to simulate actual exposure.	
Direct Reading Instruments	***Examples :*** Gas detector tubes, sound level meters	
Biological Monitoring	***Examples :*** Blood lead test, urine analysis	

2.7. Practical Application Exercise

Scenario:

Recent measurement of a worker's exposure to industrial compound "X."

TWA-PEL for Compound X = 50 parts per million (ppm)

You're Sample Results:

- Sample 1 (4-hour duration): 30 ppm
- Sample 2 (4-hour duration): 70 ppm

Instructions:

1. Calculate the Time-Weighted Average (TWA) for the full 8-hour day.
2. Did it exceed the PEL?
3. What is the next step you recommend?
4. What type of control would you implement first?

Exercise 1: Solution Key

1. TIME-WEIGHTED AVERAGE (TWA) FORMULA

$TWA = \Sigma(Ci \times Ti) \div Ttotal$

WHERE:

Ci = Concentration during period i (ppm or mg/m³)

Ti = Duration of period i (hours)

Ttotal = Total work time (usually 8 hours)

EXAMPLE FOR 2 PERIODS:

$TWA = [(C1 \times T1) + (C2 \times T2)] \div (T1 + T2)$

ACTIVITY EXAMPLE:

$TWA = [(30 \times 4) + (70 \times 4)] \div 8 = 400 \div 8 = 50$ ppm

2. SHORT-TERM EXPOSURE LIMIT (STEL)

STEL = Average of 15-minute samples (NO time weighting - simple average)

3. CONVERSION FORMULAS

ppm to mg/m³:

mg/m³ = ppm × (Molecular Weight ÷ 24.45)

mg/m³ to ppm:

ppm = mg/m³ × (24.45 ÷ Molecular Weight)

4. EXPOSURE ASSESSMENT

CONDITION	ACTION REQUIRED
TWA < PEL	Acceptable (continue monitoring)
TWA = PEL	At limit (implement preventive controls)
TWA > PEL	Unacceptable (implement immediate controls)
Any reading > STEL	Investigate immediately
Any reading > IDLH	Evacuate immediately

5. QUICK CALCULATION TEMPLATE

Step 1: Multiply concentrations by times
Step 2: Sum all products
Step 3: Divide by total time
Step 4: Compare with PEL

MEMORY AID:

"Concentration × Time, Sum, Divide by Total Time"

6. COMMON MISTAKES TO AVOID

1. Don't use simple average (must weight by time)
2. Ensure consistent units (hours, ppm)
3. Check both TWA and STEL if applicable
4. Consider partial work shifts
5. Document all calculations

7. PRACTICE FORMULA

For the standard 8-hour shift with two measurements:

$TWA = (4C1 + 4C2) \div 8 = (C1 + C2) \div 2$

2.8. Environmental Monitoring: From Workplace to Surroundings

Internal Focus (Worker Protection)

- Monitoring air quality inside the facility
- Measuring worker exposure levels

External Focus (Community & Environment Protection)

- Monitoring stack emissions (outdoor air)
- Monitoring industrial wastewater before discharge
- Monitoring hazardous waste before disposal
- Ambient monitoring (soil, groundwater) around facility



Objective: Ensuring compliance with national environmental laws and protecting the community.

2.9. Regulatory Framework in Algeria

Table II.9: Algerian Regulatory Framework

Area	Regulation	Purpose
Occupational Health	Executive Decree 91-05	Listing occupational diseases and exposure limits
Air Emissions	Joint Ministerial Order 06-198	Permissible air emission standards
Wastewater	Joint Ministerial Order 06-199	Permissible wastewater discharge standards
Inspection	Labor Inspectorate, Wilaya Directorate for the Environment	Enforcement and monitoring

2.10. Modern Challenges and Trends

Table II.10: Modern Challenges and Trends

Challenge/Trend	Description
Mixed Hazards Challenge	Concurrent exposure to multiple hazards (noise + solvents)
Emerging Hazards	Nanoparticles, psychosocial health risks
Trend Towards Continuous Monitoring	Smart sensors and Industrial IoT (IIoT) for real-time data
Importance of Documentation	Records as evidence of compliance and prevention

SECTION 3: Risk Analysis Methodology

3. Environmental Management in Industrial Facilities

3.1. Learning Objectives

At the end of this section, the learner will be able to:

- Explain the evolution of environmental thinking in industry;
- Define Environmental Management System (EMS) and its importance;
- Apply the PDCA cycle (Plan-Do-Check-Act) in environmental management;
- Distinguish between environmental aspects and environmental impacts;
- Use the Environmental Significance Matrix for priority setting;
- Understand pollution prevention strategies at source.

3.2. Evolution of Environmental Thinking in Industry

Stage 1: The Age of Indifference (Pre-1970)

- ✓ Philosophy: "Business as usual"
- ✓ Practice: Focus on production at any cost
- ✓ Model: Linear (Take - Make - Dispose)

Stage 2: The Treatment Era (1970-1990)

- ✓ Philosophy: "Cleaning up the mess"
- ✓ Practice: End-of-pipe treatment
- ✓ Problem: High costs, transferring the problem (air→water)

Stage 3: The Prevention Era (1990-2010)

- ✓ Philosophy: "Prevention is better than cure"
- ✓ Practice: Cleaner Production
- ✓ Focus: Resource efficiency, waste reduction at source

Stage 4: The Sustainability Era (2010-Present)

- ✓ Philosophy: "Integrated responsibility"
- ✓ Practice: Comprehensive Environmental Management
- ✓ Model: Circular (Design - Make - Use - Return)

3.3. Environmental Management System (EMS)

3.3.1. Definition

What is EMS?

An **Environmental Management System (EMS)** is a sustainable organizational framework that links policies, procedures, and resources to achieve environmental objectives. It is a continuous process, not a one-time project.

Practical Essence of EMS

Aspect	*Description*
Full Integration	Environmental dimension in every decision – from purchasing to production
Organizational Culture	A new way of thinking, not just procedures
Dual Benefit	Protects the environment and enhances efficiency

3.3.2. Why is EMS Essential? - Four Key Reasons

Why EMS is Essential

Reason	***Description***	***Example***
A.Legal Compliance	Avoiding violations, fines, and shutdown penalties; Proactivity before laws change; Compliance documentation	Fines for non-compliance; environmental permits
B.Market Advantages	Consumer demand (68% prefer eco-friendly products); ISO 14001 requirement for exporting; Brand differentiation	International contracts; green marketing
C.Financial Savings	30%-40% savings on energy and water; 25% reduction in waste; Reduced disposal and treatment costs	Lower operational costs; resource efficiency
D.Reputation and Trust	Positive community relations; Attracting talent; Investment appeal	Community trust; employee retention; investor preference

Strategic Transformation: EMS as a Lever

FROM	**TO**
Legal Burden	Competitive Advantage
Additional Costs	Sustainable Financial Savings
Mandatory Responsibility	Marketing Opportunity
Potential Risks	Smart Investment

3.4. The Continuous Improvement PDCA Cycle in ISO 14001

P - PLAN (Smart Planning)

Focus: Deep understanding before starting

Foundation: Identify high-impact risks first

Output: Practical, realistic action plan with timelines

D - DO (Organized Implementation)

Principle: Integration into daily work, not a separate addition

Requirements: Clear responsibility + Adequate training + Appropriate resources

Goal: Transform plans into tangible actions

C - CHECK (Honest Evaluation)

Approach: Measurement with numbers, not impressions

Transparency: Acknowledging mistakes and learning from them

Comparison: Against objectives and global best practices

A - ACT (Continuous Learning)

Correction: Addressing root causes, not surface symptoms

Institutionalization: Turning lessons into permanent policies

Development: Continuously updating the system with changes

The Big Picture: *(A continuous, never-ending cycle)*

Plan→ Do → Check → Act → Improve → Return to Plan

Note: *ISO 14001 is not a rigid certificate, but an organizational way of life for continuous environmental improvement. Success is not about achieving perfection, but about learning from every experience and evolving continuously.*



Figure II.5: The PDCA Cycle

3.5. Environmental Aspects vs. Environmental Impacts

3.5.1. Critical Distinction

Table II.11: Environmental Aspects vs. Environmental Impacts

Aspect	Environmental Aspect	Environmental Impact
Definition	An element of our processes with potential interaction with the environment	The change that occurs in the environment due to our aspect
Characteristics	• Direct and measurable • Within our site boundaries • We can control it	• May be cumulative or delayed • Often outside our site boundaries • We are responsible for it
Practical Examples	• Amount of fuel consumed • Volume of waste generated • Concentration of emissions from a stack	• Increase in global carbon emissions • Groundwater pollution • Loss of biodive

Golden Rule: ***We control aspects to mitigate impacts.***

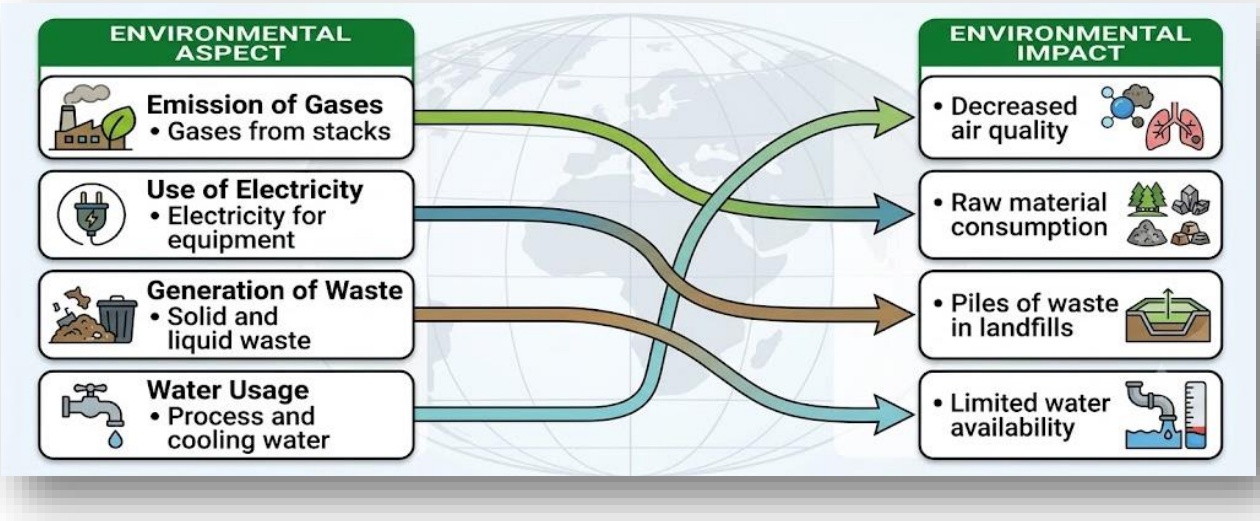


Figure II.6: Environmental Aspects vs. Impacts

3.6. Environmental Aspects Analysis

Practical Methodology: Complete Environmental Inventory



Step 1: Understanding Processes (Detailed Mapping)

Action	Description
Material flow mapping	From input to output
Identifying key transformation points	Where changes occur
Documenting conditions	Normal and emergency operating conditions

Step 2: Measuring Inputs (What Comes In)

Input Type	Questions to Consider
Raw Materials	Quantities, purity, supply sources
Energy	Electricity, fuel, steam - efficiency and waste
Water	Consumption, quality, reuse

Step 3: Measuring Outputs (What Goes Out)

Output Type	Questions to Consider
Products	Percentage, defects, lifespan
Emissions	Air (direct, indirect), noise, heat
Waste	Solid, liquid, hazardous - composition, volume, cost

Step 4: Significance Assessment (Strategic Filter)

Criteria	Description
Impact	Magnitude of environmental effect
Frequency	How often the aspect occurs
Legal Sensitivity	Regulatory requirements
Reputation Risks	Public perception

Priorities: *Focus on the 20% that cause 80% of the impact (Pareto Principle).*

3.7. Practical Application Exercise

Exercise 1: *Identifying Aspects and Impacts*

Scenario: Vegetable Canning Factory

Main Processes

Process	*Description*
Vegetable Receiving	Cleaning, sorting, storage
Manufacturing	Cutting, cooking, canning
Packaging	Packaging, storage, shipping
Support	Maintenance, cleaning, energy management

Additional Information:

- Uses 1000 m^3 of water daily
- Generates 5 tons of organic waste daily
- Operates 24 hours using fuel boilers
- Close to a residential area

Task:

6. For each process, identify two main environmental aspects
7. For each aspect, describe the potential environmental impact
8. Rank aspects by priority using:
   - Impact magnitude (1-10)
   - Probability (1-10)
   - Community sensitivity (1-5)

Tool: Environmental Significance Matrix

Exercise 1: Solution Key

1. Environmental Priority Matrix

#	Environmental Aspect	Impact	Priority	Main Action
1	Boiler energy consumption	High carbon emissions	★ ★ ★ ★ ★	Convert to renewable energy
2	Wash water pollution	Groundwater pollution	★ ★ ★ ★ ★	Water recycling system
3	Plastic waste	Long-term environmental pollution	★ ★ ★ ★	Reduce packaging + recycling

3. Quick Implementation Matrix

Priority	Aspect	Action	Time	Cost	Return
High	Energy	Renewable energy	6 months	Medium	30% saving
High	Water	Recycling	4 months	High	40% saving
High	Plastic	New design	3 months	Low	50% reduction

2. Quantitative Assessment Matrix

Aspect	Impact (10)	Probability (10)	Community (5)	Total
Energy	9	10	4	23
Water	8	9	5	22
Plastic	8	8	4	20
Chemicals	7	7	3	17
Steam	7	6	2	15

5. Matrix Conclusion

Focus on only 3 aspects:

- Energy ← Improve efficiency
- Water ← Recycle and reuse
- Plastic ← Reduce and recycle

Principle: 20/80 rule

Result: Treating 20% of aspects solves 80% of environmental problems

"The matrix answers: What, Why, How, and When"

4. Decision Matrix

Immediate Treatment (Total ≥20):
- Boiler energy consumption
- Wash water pollution
- Plastic waste

Short-term Treatment (Total 15-19):
- Chemical cleaning agents
- Lost cooking steam

Routine Monitoring (Total <15):
- Vegetable waste
- Shipping emissions

3.8. Pollution Prevention Strategies at Source

Most Effective

LEVEL 1: PREVENTION THROUGH DESIGN ☆ ☆ ☆ ☆ ☆

•Green Design: Environmentally friendly products from start

• Modeling & Simulation: Predicting problems before implementation

• Supplier Selection: Partners with strong environmental performance

LEVEL 2: PROCESS IMPROVEMENT ☆ ☆ ☆ ☆

• Preventive Maintenance: Preventing leaks and waste

• Smart Monitoring: Control systems for efficiency

• Operator Training: Improving behaviors and skills

LEVEL 3: INTERNAL RECYCLING ☆ ☆ ☆

• Closed Loops: Reusing water, chemicals, materials

• Energy Recovery: Capturing waste heat and gases

• Reuse: Packaging, containers, materials

LEVEL 4: END-OF-PIPE TREATMENT ☆ ☆

• Centralized Treatment: Specialized treatment units

• Responsible Disposal: Through certified specialists

• Continuous Monitoring: Even after disposal

Least Effective

Core Principle*: *"Start from the top: Prevent → Improve → Recycle → Treat"

Each step downward = Higher costs + Lower effectiveness

Success Example: Algerian Chemical Plant

Problem: High costs for purchasing new solvents

Solution: System for recycling used solvents

Result: 30% reduction in operational costs

Period: Return on investment within 8 months

3.9. Benefits of Implementing an Environmental Management System

Table II.12: Integrated Benefit Package

Benefit Type	Specific Benefits
Tangible Benefits (Direct Measurement)	• **Financial Savings:** Energy (15-30%), Water (20-50%), Raw Materials (10-25%), Waste (40-80% reduction in disposal costs)
	• **Cost Avoidance:** Fines, violations, compensation, litigation
Operational Benefits (Internal Efficiency)	• Improved product quality
	• Increased worker productivity
	• Reduced breakdowns and downtime
	• Improved work environment
Intangible Benefits (Strategic Value)	• **Competitive Position:** ISO 14001 certification, Preference from major suppliers, International markets (especially Europe), Improved credit rating
	• **Social Capital:** Local community trust, Attracting exceptional employees, Positive relations with regulatory bodies, Brand reputation

Real Case: An automobile company saved $400 million through an integrated environmental program.

SECTION 4: Industrial Waste Management

4. Industrial Waste Management

4.1. Learning Objectives

At the end of this section, the learner will be able to:

- Classify industrial waste and apply the waste management hierarchy;
- Understand the "Cradle-to-Grave" responsibility principle;
- Design safe storage and treatment for hazardous waste;
- Understand the legal framework and circular economy concept.

4.2. Industrial Waste: Challenge and Opportunity

4.2.1. Scale and Problem

Industrial waste represents one of the most significant environmental challenges facing modern industries. The scale of waste generation and its associated costs make effective waste management a critical priority.

- Industrial facilities generate **40-60% of solid waste** in industrial cities.
- **Hidden Cost:** Material purchase + manufacturing energy + disposal cost.
- Waste generation is not only an environmental burden but also a reflection of process inefficiency.
- Poor waste management leads to legal liabilities, environmental degradation, and reputational damage.

4.2.2. Intellectual Shift

The transition from traditional to modern waste management requires a fundamental change in perspective. Rather than viewing waste as a burden to be disposed of, it should be recognized as an indicator of process inefficiency and a valuable resource that can be recovered, reused, or recycled.

Traditional View	**Modern View**
Waste = burden + additional cost	**Waste = inefficiency indicator + wasted resources**

Smart Management Hierarchy:

Prevention → Reduction → Reuse → Recycling → Recovery → Treatment → Disposal

4.3. Classification of Industrial Waste

Table II.13: Classification of Industrial Waste

Category	*Characteristics*	*Examples*	
Hazardous Waste (Primary Focus)	Flammable, corrosive, toxic, reactive	• Used solvents (acetone, toluene) • Concentrated acids and alkalis • Used lubricating oils • Lead-acid batteries • Industrial medical waste	
Non-Hazardous Waste (Ordinary)	Non-toxic, non-reactive	• Uncontaminated metal scrap • Paper and cardboard waste • Clean plastic residues • Packaging waste	
Inert Waste	Chemically inactive, non-reactive	• Construction and demolition debris • Some types of ash	

4.4. Integrated Waste Management Hierarchy

From best practice

1. Prevention

Designing processes that don't generate waste from outset

Example: modifying product design to reduce material usage

2. Reduction

Improving efficiency to reduce waste quantity

Example: improving cutting precision to reduce scraps

3. Reuse

Using waste for the same purpose without treatment

Example: reusing containers and packaging

4. Recycling

Treating waste to extract raw materials

Example: recycling metals, recovering solvents

5. Recovery

Extracting energy from waste

Example: using waste as alternative fuel

6. Treatment

Reducing waste hazard before disposal

Example: solidification/stabilization, chemical treatment

7. Disposal

Landfilling in secure facilities

Example: licensed hazardous waste landfills

To worst practice



Figure II.7: Integrated Waste Management Hierarchy

4.5. Hazardous Waste Responsibility Chain

"Cradle-to-Grave" Principle

1. PRODUCER (Your Facility) - Primary Responsibility

Obligations:

• Correct identification of waste

• Accurate classification and labeling

• Safe temporary storage

• Selection of licensed transporter and processor

2. TRANSPORTER (Collector) - Secondary Responsibility

Obligations:

• Obtaining transportation license

• Using safe transport means

• Maintaining transport documents

3. PROCESSOR/DISPOSER - Final Responsibility

Obligations:

• Safe and effective treatment

• Responsible final disposal

• Issuing disposal certificates

Tracking Document (Waste Manifest):

- Waste passport from origin to disposal
- Signed by all parties
- Kept for at least 10 years

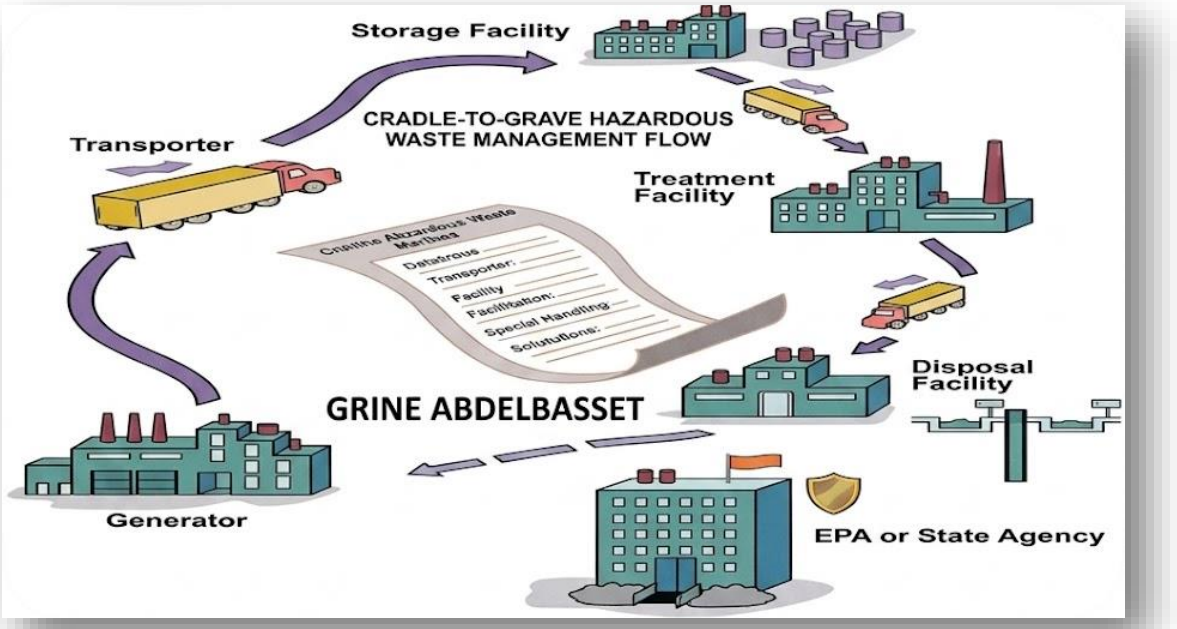


Figure II.8: Cradle-to-Grave Chain

4.6. Practical Application Exercise

***Exercise 1:** Developing a Waste Management Plan*

Scenario:

Metal forming factory generates the following waste types:

Type	*Description*
A	Wastewater treatment sludge containing heavy metals
B	Used lubricating oils contaminated with metals
C	Clean iron scrap
D	Plastic packaging waste

Instructions:

1. Classify each type (hazardous/non-hazardous)
2. Suggest two hierarchy options for each type
3. Design a safe temporary storage area for types A and B
4. Identify required tracking documents

Exercise 1: Solution Key

1. Classification:

Type	*Description*	*Classification*
A	Heavy metal sludge	**Hazardous** (toxic)
B	Contaminated oils	**Hazardous** (toxic + flammable)
C	Iron scrap	**Non-hazardous**
D	Plastic	**Non-hazardous**

2. Treatment Options:

Type	*Hierarchy Option 1*	*Hierarchy Option 2*
A (Heavy metal sludge)	Solidification/Stabilization	Chemical precipitation
B (Contaminated oils)	Recycling/Recovery	Energy recovery
C (Iron scrap)	Direct recycling	Reuse
D (Plastic)	Recycling	Reduction at source

3. Temporary Storage Design:

Requirement	*Specification*
Location	Separate covered area

Containers	Leak and corrosion resistant
Safety	Impermeable floor + emergency collection basin
Documentation	Clear warning labels

4. Required Documents:

- Daily internal waste log
- Official tracking form signed by all parties
- Transporter and processor licenses
- Final disposal certificate

5. Implementation Timeline:

Period	Action
Weeks 1-2	Design and equipment purchase
Week 3	Employee training
Week 4	Implementation and review

Expected Results:

- Save 40% of disposal costs
- Reduce 25% of waste quantity within 6 months
- Ensure 100% compliance with Law 01-19

4.7. Safe Temporary On-Site Storage

Basic Requirements

Table II.14: Temporary Storage Requirements

Requirement	Description
1. Separation and Classification	Preventing mixing of incompatible wastes; Designating separate areas for each type
2. Appropriate Containers	Leak and corrosion resistant; Tightly sealed; In good condition (no rust or cracks)
3. Clear Labeling	Waste name and composition; International hazard symbols; Generation date and quantity
4. Designated Location	Covered area with impermeable flooring; Away from ignition and reaction sources; Equipped with secondary containment (berms)
5. Records and Management	Daily log of incoming and outgoing quantities; Regular inspection program; Spill emergency plan



Figure II.9: Safe Temporary Storage

4.8. Pre-Disposal Treatment Techniques

Table II.15: Pre-Disposal Treatment Techniques

Technique	*Description*	*Application*
Solidification/Stabilization	Mixing liquid waste with binding materials (cement, gypsum); Producing solid blocks resistant to leaching	Stabilizing metal-containing sludge
Chemical Treatment	Neutralizing acids and alkalis; Precipitating metals from solutions; Oxidizing or reducing toxic compounds	Metal precipitation, pH neutralization
Thermal Treatment (Incineration)	In licensed furnaces with control systems; With exhaust gas treatment equipment; Condition: 99.99% destruction efficiency	Organic waste destruction
Biological Treatment	Using microorganisms to degrade organic waste	Food waste treatment

4.9. Law 01-19: Your Professional Protection Shield

Warning Scenario:

A chemical plant disposed of hazardous waste illegally. Discovered by the Ministry of Environment during a surprise inspection.

Question: What consequences will you face as a responsible engineer?

3 Devastating Consequences:

1. **Fine:** 10 million dinars ← Cost of a new production line!
2. **Shutdown:** 6-12 months ← Complete loss of market and clients
3. **Imprisonment:** Criminal liability ← End of your professional career

3 Protections Provided by the Law:

- ✓ **Immunity:** Your legal documents protect you from accountability
- ✓ **Distinction:** 87% of companies prefer the compliant engineer
- ✓ **Savings:** Law compliance saves 15-30% of costs

Conclusion:

"**Law 01-19: Not an obstacle, but a success map for the smart and responsible engineer**"

4.10. Circular Economy: Strategic Vision

Traditional Linear Model:

Take → Make → Use → Dispose

• Resource depletion

• Waste accumulation

• High environmental costs

Ambitious Circular Model:

Design → Make → Use → Reuse/Remanufacture/Recycle

• Resource preservation

• Waste reduction

• Added economic value

Engineer's Role in Circular Economy:

Area	*Contribution*
Design	Products easy to disassemble and recycle
Operations	Closed-loop systems for materials and energy
Innovation	New business models (leasing instead of selling)

Successful Initiatives:

Sector	*Initiative*
Industries	Metal recovery from electronic waste
Services	Chemical leasing instead of selling
Products	Modular design for repair and upgrade

SECTION 5: Sustainability and Sustainable Development - Integrated Case Study

5. Sustainability and Sustainable Development

5.1. Learning Objectives

At the end of this section, the learner will be able to:

- Define sustainability and apply LCA principles;
- Develop integrated solutions for industrial sustainability;
- Analyze challenges and opportunities in the Algerian context.

5.2. What is Sustainability?

5.2.1. Classic Definition (Brundtland Commission, 1987)

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

5.2.2. Three Interconnected Dimensions

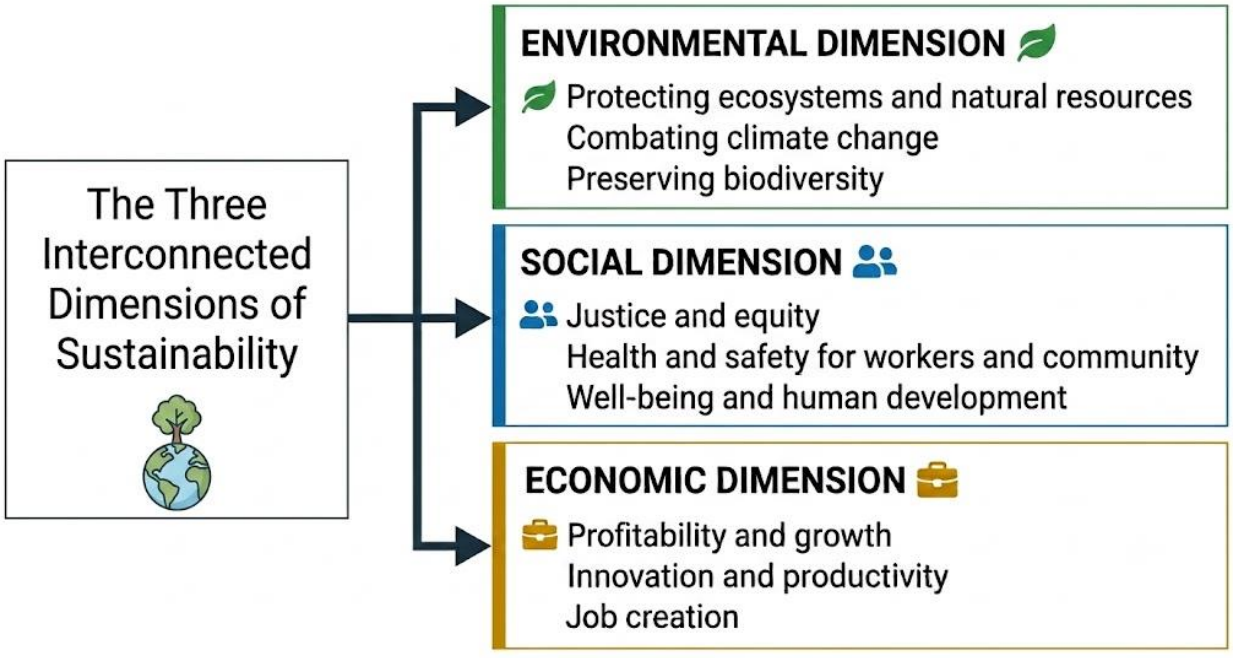


Figure II.9: the three interconnected dimensions of sustainability

Engineer's Critical Role: Achieving balance between these dimensions in technical designs and decisions.

5.3. Life Cycle Assessment (LCA)

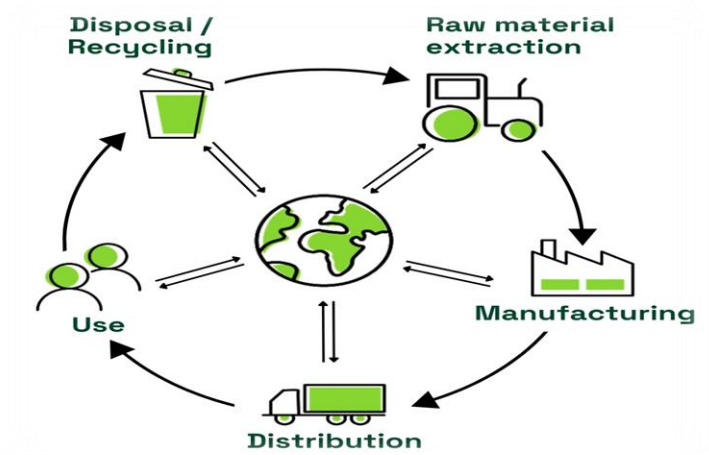
5.3.1. Core Idea

We don't judge a product only from its use phase, but evaluate its environmental impacts throughout its entire life cycle.

Simply put: *"Think about the product's end when you start designing it."*

5.3.2. Practical Example

- **Product:** Electric car
- **Problem:** Lithium batteries
- **Solution:** Design that facilitates recycling from the beginning



5.4. Integrated Case Study: Gulf Electroplating Factory

5.4.1. Current Situation (Traditional Linear Model)

Activity: Electroplating car parts with chromium layer

Location: Industrial area near residential housing

Main Problems:

Problem	*Description*
High water and energy consumption	Inefficient resource use
Wastewater loaded with hexavalent chromium	Toxic and hazardous
Hazardous sludge waste containing heavy metals	Difficult and costly to dispose
Community dissatisfaction	Odors and visual pollution
Frequent fines from regulatory authorities	Legal and financial penalties

Basic Data:

Parameter	*Value*
Water consumption	500 m³/day
Energy consumption	8000 kWh/day
Hazardous waste	2 tons/month
Annual fines	5 million DZD
Community complaints	15 complaints/month average

5.4.2. Sustainability Transformation Plan

The factory requires a comprehensive transformation plan toward sustainability covering all three dimensions: environmental, social, and economic.

A. Environmental Solutions

Solution	*Description*	*Cost*	*Payback*
Closed Water System	95% water recycling	200 million DZD	14 months
Chromium Replacement	Switch from hexavalent to trivalent chromium	50 million DZD	–
Solar Energy	Installation of solar panels	150 million DZD	5 years

B. Social Solutions

Solution	*Description*	*Cost*	*Impact*
Health Monitoring	Regular worker checkups	5 million DZD/year	Reduces absenteeism 30%
Community Transparency	Open meetings + display boards	2 million DZD/year	Builds trust
Community Programs	Garden + training programs	10 million DZD (initial)	Positive relations

C. Economic Solutions

Solution	*Description*
New Business Models	Product-as-service, facility sharing, recycled materials trade
Incentive Package	ISO certification, tax exemptions, green financing
Funding Plan	400 million DZD (50% green loan, 30% self-investment, 20% government grants)

5.4.3. Expected Results (Year 3)

Result	Impact
Annual Savings	300 million DZD
Sales Increase	20% due to environmental certification
Elimination of Fines	From 5 million DZD/year to zero

Basic Principle: *Every dinar invested in sustainability returns three: one environmental, one social, one economic.*

5.5. Sustainability in the Algerian Context: Challenges & Opportunities

5.5.1. Challenges

Challenge	Description
Water Scarcity	300 m^3/person/year (below global poverty line)
Fossil Fuel Dependence	98% reliance (unsustainable)
Limited Infrastructure	For waste and renewable energy
Cultural Resistance	To change in organizations

5.5.2. Golden Opportunities

Opportunity	Description
Solar Energy	3000 hours/year (untapped treasure)
Wind Energy	Long coastline with excellent wind speeds
Supportive Laws	04-09 (energy) and 01-19 (waste)
European Demand	Partners require environmental compliance

Note:

"Our limitations create our opportunities, and our engineers transform them into reality."

5.5.3. Algerian Engineer's Role

Role	Description
Adapter	Solutions that fit our resources
Innovator	Using intelligence to compensate for shortages
Leader	Leading transformation in industrial institutions

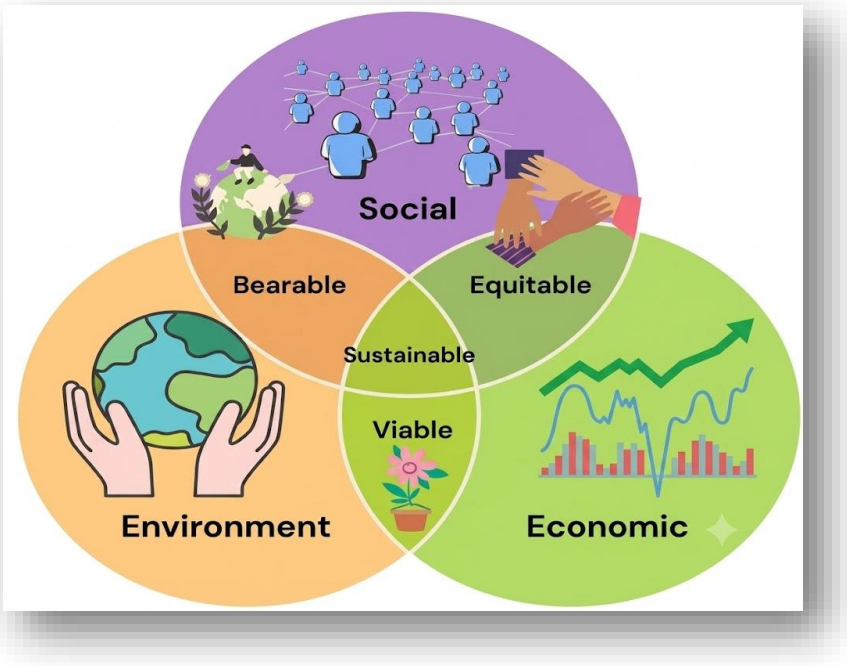


Figure II.10: Sustainability Challenges and Opportunities in Algeria

6. Conclusion

This chapter extended the HSE framework from accident prevention to the broader scope of occupational health and environmental protection. It highlighted the critical distinction between safety (immediate effects) and health (chronic, delayed effects), and emphasized the importance of understanding exposure pathways to prevent occupational diseases. The principles of industrial hygiene, environmental monitoring, and systematic management through EMS and PDCA were presented as essential tools for protecting both workers and the environment. The chapter also demonstrated how waste can be transformed from a burden into an economic opportunity through the waste management hierarchy and circular economy principles. Ultimately, the integration of environmental, social, and economic dimensions is essential for achieving sustainable development in industrial contexts.

Chapter II Summary: From Worker Protection to Global Sustainability

1. Occupational Health vs. Safety

Concept	Description
Safety	Preventing immediate accidents (falls, fires, shocks)
Health	Preventing chronic exposure (diseases, poisoning, hearing loss)
Exposure Pathway	Source → Pathway → Receiver

2. Prevention Hierarchy for Health Hazards

Level	Control Type
1	ELIMINATION (Most Effective)
2	SUBSTITUTION
3	ENGINEERING CONTROLS
4	ADMINISTRATIVE CONTROLS
5	PPE (Least Effective)

3. Industrial Hygiene (ANTE)

Category	Hazards
Chemical	Vapors, dusts, gases, fumes
Physical	Noise, radiation, extreme temperatures
Biological	Bacteria, viruses, fungi, molds
Ergonomic	Poor posture, repetitive motion, heavy lifting

4. The RECCE Cycle

Recognition → Evaluation → Comparison → Control → Re-evaluation

5. Occupational Exposure Limits (OELs)

Type	Description
TWA-PEL	8-hour average concentration
STEL	15-minute average (short-term)
IDLH	Immediate threat to life or health

6. Environmental Management

Concept	Description
EMS	Systematic framework for environmental objectives
PDCA	Plan → Do → Check → Act (Continuous improvement)
Environmental Aspect	What we control (e.g., fuel consumption)
Environmental Impact	What we mitigate (e.g., emissions)

7. Waste Management Hierarchy

Prevention → Reduction → Reuse → Recycling → Recovery → Treatment → Disposal

8. Cradle-to-Grave Responsibility

Producer → Transporter → Processor/Disposer

9. Circular Economy

Model	Description
Linear	Take → Make → Use → Dispose
Circular	Design → Make → Use → Reuse/Recycle

10. Sustainability Dimensions

Dimension	Focus
Environmental	Protecting ecosystems and resources
Social	Justice, health, well-being
Economic	Profitability, growth, jobs

11. Key Principles Learned

- **Proactivity:** Prevention is better than cure
- **Measurement:** What cannot be measured cannot be managed
- **Integration:** Environment, economy, and society are inseparable
- **Responsibility:** The essence of engineering professionalism
- **Continuity:** Continuous improvement is a necessity

Final Message:

"As future engineers, you are not just designers or operators, but guardians of the future. Every technical decision you make has an impact beyond the four walls of your factory."

Core Philosophy:

- **From Theory to Application**
- **From Worker Protection to Global Sustainability**
- **From Individual to System**

GLOSSARY

Key HSE Terms, Definitions & Acronyms

This section provides comprehensive definitions for fundamental terminology, safety concepts, industrial hygiene indicators, and international acronyms referenced in this course.

ENGLISH-FRENCH-ARABIC GLOSSARY

UNIT 1: RISK ASSESSMENT & ACCIDENT ANALYSIS

A. Risk Management Terms

English	Français	العربية
Risk Assessment	Évaluation des risques	تقييم المخاطر
Hazard Identification	Identification des dangers	تحديد المخاطر
Risk Analysis	Analyse des risques	تحليل المخاطر
Risk Evaluation	Évaluation des risques	تقييم المخاطر
Risk Control	Contrôle des risques	السيطرة على المخاطر

B. Analysis Methods

English	Français	العربية
Root Cause Analysis	Analyse des causes racines	تحليل الأسباب الجذرية
Failure Mode Analysis	Analyse des modes de défaillance	تحليل أنماط الفشل
FMEA	AMDEC	تحليل أنماط الفشل وأثارها
Fault Tree Analysis	Arbre de défaillance	شجرة الفشل
HAZOP	Étude HAZOP	تحليل المخاطر وقابلية التشغيل

C. Accident Investigation

English	Français	العربية
Incident Report	Rapport d'incident	تقرير الحادث
Near Miss	Presque accident	حادثة كادت أن تحدث
Accident Investigation	Enquête d'accident	تحقيق الحوادث
Corrective Action	Action corrective	إجراء تصحيحي
Preventive Action	Action préventive	إجراء وقائي

UNIT 2: OCCUPATIONAL HEALTH & ENVIRONMENTAL PROTECTION

A. Occupational Health

English	Français	العربية
Industrial Hygiene	Hygiène industrielle	النظافة المهنية
Occupational Exposure Limits	Valeurs limites d'exposition	حدود التعرض المهنية
Time-Weighted Average	Valeur Moyenne d'Exposition	المتوسط المرجح زمنياً
Short-Term Exposure Limit	Valeur Limite d'Exposition	حد التعرض القصير
Biological Monitoring	Surveillance biologique	المراقبة البيولوجية

B. Environmental Protection

English	Français	العربية
Environmental Management System	Système de management environnemental	نظام الإدارة البيئية
Life Cycle Assessment	Évaluation du cycle de vie	تقييم دورة الحياة
Circular Economy	Économie circulaire	الاقتصاد الدائري
Pollution Prevention	Prévention de la pollution	منع التلوث
Waste Management	Gestion des déchets	إدارة النفايات

C. Hazardous Materials

English	Français	العربية
Hazardous Waste	Déchets dangereux	نفايات خطرة
Chemical Safety	Sécurité chimique	السلامة الكيميائية
Material Safety Data Sheet	Fiche de données de sécurité	صحيفة بيانات السلامة
Personal Protective Equipment	Équipement de protection individuelle	معدات الحماية الشخصية
Emergency Response	Intervention d'urgence	الاستجابة للطوارئ

COMMON TERMS - BOTH UNITS

A. Measurement & Monitoring

English	Français	العربية
ppm (parts per million)	ppm (parties par million)	جزء في المليون
mg/m³	mg/m³	ملغم/متر مكعب
Monitoring	Surveillance	المراقبة
Sampling	Échantillonnage	أخذ العينات
Calibration	Étalonnage	المعايرة

B. Management Systems

English	Français	العربية
Documentation	Documentation	التوثيق
Audit	Audit	تدقيق
Compliance	Conformité	الامتثال
Continuous Improvement	Amélioration continue	التحسين المستمر
Performance Indicator	Indicateur de performance	مؤشر الأداء

C. Safety Concepts

English	Français	العربية
Safety Culture	Culture de sécurité	ثقافة السلامة
Training	Formation	التدريب
Competence	Compétence	الكفاءة
Emergency Plan	Plan d'urgence	خطة الطوارئ
First Aid	Premiers secours	الإسعافات الأولية

LEGAL & REGULATORY TERMS

A. Standards & Regulations

English	Français	العربية
Technical Standards	Normes techniques	المعايير الفنية
Legal Requirements	Exigences légales	المتطلبات القانونية
Certification	Certification	الشهادة
Accreditation	Accréditation	الاعتماد
Inspection	Inspection	التفتيش

B. Algerian Legislation (Arabic-French)

Français	العربية
Loi 90-11	القانون 90-11
Loi 01-19	القانون 01-19
Loi 03-10	القانون 03-10
Décret exécutif 91-05	المرسوم التنفيذي 91-05
Arrêté ministériel 06-198	القرار الوزاري 06-198

TOP 20 ESSENTIAL TERMS

Rank	English	Français	العربية
1	Risk Assessment	Évaluation des risques	تقييم المخاطر
2	Industrial Hygiene	Hygiène industrielle	النظافة المهنية
3	Occupational Exposure Limits	Valeurs limites d'exposition	حدود التعرض المهنية
4	Root Cause Analysis	Analyse des causes racines	تحليل الأسباب الجذرية
5	Environmental Management System	Système de management environnemental	نظام الإدارة البيئية
6	Hazardous Waste	Déchets dangereux	نفايات خطرة
7	Time-Weighted Average	Valeur Moyenne d'Exposition	المتوسط المرجح زمنياً
8	Circular Economy	Économie circulaire	الاقتصاد الدائري
9	Pollution Prevention	Prévention de la pollution	منع التلوث
10	Safety Culture	Culture de sécurité	ثقافة السلامة
11	FMEA	AMDEC	تحليل أنماط الفشل وأثارها
12	Medical Surveillance	Surveillance médicale	المراقبة الطبية
13	Life Cycle Assessment	Évaluation du cycle de vie	تقييم دورة الحياة
14	Personal Protective Equipment	Équipement de protection individuelle	معدات الحماية الشخصية
15	Emergency Response	Intervention d'urgence	الاستجابة للطوارئ
16	Compliance	Conformité	الامتثال
17	Training	Formation	التدريب
18	Audit	Audit	تدقيق
19	Continuous Improvement	Amélioration continue	التحسين المستمر
20	Documentation	Documentation	التوثيق

ACRONYMS & ABBREVIATIONS

A. Common Acronyms

Acronym	English	Français	العربية
OEL	Occupational Exposure Limit	Valeur Limite d'Exposition	حد التعرض المهني
TWA	Time-Weighted Average	Valeur Moyenne d'Exposition	المتوسط المرجح زمنياً
STEL	Short-Term Exposure Limit	Valeur Limite d'Exposition à court terme	حد التعرض القصير
IDLH	Immediately Dangerous to Life or Health	Danger immédiat pour la vie ou la santé	خطر فوري على الحياة والصحة
PPE	Personal Protective Equipment	Équipement de protection individuelle	معدات الحماية الشخصية
MSDS	Material Safety Data Sheet	Fiche de données de sécurité	صحيفة بيانات السلامة

B. Standard References

Acronym	English	Français	العربية
ISO	International Organization for Standardization	Organisation internationale de normalisation	المنظمة الدولية للمعايير
OSHA	Occupational Safety and Health Administration	Administration de la sécurité et de la santé au travail	إدارة السلامة والصحة المهنية
NIOSH	National Institute for Occupational Safety and Health	Institut national pour la sécurité et la santé au travail	المعهد الوطني للسلامة والصحة المهنية
EPA	Environmental Protection Agency	Agence de protection de l'environnement	وكالة حماية البيئة
WHO	World Health Organization	Organisation mondiale de la santé	منظمة الصحة العالمية

REFERENCES

Bibliographic references & Legal Framework

A validated compilation of core textbooks, specialized handbooks, peer-reviewed journal articles, international ISO standards, and Algerian regulatory legislation.

References

1. Core Textbooks

1. Ericson, C. A. (2022). *Hazard Analysis Techniques for System Safety* (2nd ed.). Wiley.
2. Rausand, M., & Haugen, S. (2020). *Risk Assessment: Theory, Methods, and Applications* (2nd ed.). Wiley.
3. Spellman, F. R. (2023). *Handbook of Environmental Engineering* (7th ed.). CRC Press.
4. Friend, M. A., & Kohn, J. P. (2022). *Fundamentals of Occupational Safety and Health* (8th ed.). Bernan Press.

2. Specialized Books

1. Mannan, S. (2012). *Lees' Loss Prevention in the Process Industries* (4th ed.). Butterworth-Heinemann.
2. Burgess, W. A. (1995). *Recognition of Health Hazards in Industry* (2nd ed.). Wiley-Interscience.
3. Kletz, T., & Amyotte, P. (2018). *What Went Wrong? Case Studies of Process Plant Disasters* (6th ed.). Gulf Professional Publishing.

3. Peer-Reviewed Articles

Chemical Risk Assessment:

1. Villa, V., Paltrinieri, N., & Cozzani, V. (2016). "Overview of methodology for dynamic risk analysis in chemical process plants". *Safety Science*, 86, 112–121.

Industrial Safety (HSE):

1. Swuste, P., Theunissen, J., Schmitz, P., Reniers, G., & Groeneweg, J. (2016). "Process safety indicators, a review of literature". *Safety Science*, 85, 214–224.

Circular Economy:

1. Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). "A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems". *Journal of Cleaner Production*, 114, 11–32.

4. Online Resources & Official Platforms

Official Platforms — Global:

- **US Environmental Protection Agency (EPA):** https://www.epa.gov
- **Occupational Safety and Health Administration (OSHA):** https://www.osha.gov
- **National Institute for Occupational Safety and Health (NIOSH):** https://www.cdc.gov/niosh
- **World Health Organization (WHO) — Occupational Health:** https://www.who.int/occupational_health
- **European Agency for Safety and Health at Work (EU-OSHA):** https://osha.europa.eu

Tools & Applications:

- **OSHA Hazard Identification Training Tool:** https://www.osha.gov/hazidentify
- **NIOSH Pocket Guide to Chemical Hazards (NPG):** https://www.cdc.gov/niosh/npg
- **EPA EnviroAtlas:** https://www.epa.gov/enviroatlas

5. International Standards & Systems

Risk Management:

- **ISO 31000:2018** — Risk management — Guidelines.
- **IEC/ISO 31010:2019** — Risk management — Risk assessment techniques.

Health & Safety:

- **ISO 45001:2018** — Occupational health and safety management systems — Requirements with guidance for use.
- **ACGIH (2024)** — TLVs and BEIs: Threshold Limit Values for Chemical Substances and Physical Agents.

- **OSHA (2023)** — Occupational Safety and Health Standards (29 CFR 1910).

Environmental Management & Harmonization:

- **ISO 14001:2015** — Environmental management systems — Requirements with guidance for use.
- **ISO 14040:2006** — Environmental management — Life cycle assessment — Principles and framework.
- **United Nations (2023)** — Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (10th revised ed.).

6. Legislation & Legal Frameworks

Algerian Legislation:

Laws:

- **Law No. 88-07** of January 26, 1988 — Related to occupational health, safety, and occupational medicine.
- **Law No. 01-19** of December 12, 2001 — Related to waste management, disposal, and control.
- **Law No. 03-10** of July 19, 2003 — Related to environmental protection in the context of sustainable development.
- **Law No. 83-13** of July 2, 1983 — Related to work accidents and occupational diseases (amended and supplemented).

Executive Decrees & Regulations:

- **Executive Decree No. 06-138** of April 15, 2006 — Regulating atmospheric emissions of gases, smoke, vapors, and particles.
- **Executive Decree No. 06-141** of April 19, 2006 — Setting limit values for industrial liquid effluent discharges.
- **Interministerial Order** of May 5, 1996 — Establishing the official list of occupational diseases (amended and supplemented).

International Laws & Directives:

- **European Union (2006):** REACH Regulation (EC No 1907/2006) — Registration, Evaluation, Authorisation and Restriction of Chemicals.
- **United States (1990/2021):** Clean Air Act Amendments.
- **United Kingdom (1974):** Health and Safety at Work etc. Act 1974.

📚 **HSE - Industrial Installations**

📌 **Assessment**The evaluation of this module is structured as follows:

- **Final Exam:** 80% of the total grade (written exam covering all chapters)
- **Continuous Assessment:** 20% of the total grade

The continuous assessment (20%) is distributed as follows:

- **Quizzes:** 10%
- **Workshops:** 7%
- **Participation:** 3%

Total: 20 points