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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

Course

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Foreword

This course handout is intended for third-year students in Mechanical Construction and Industrial Maintenance programs. It will enable them to acquire the fundamental concepts related to the environment and sustainable development.

The first chapter introduces the concept of the environment, followed by a second chapter devoted to the concept of sustainable development. The third chapter deals with the environment and resources, while the fourth addresses the issue of substances. Finally, the fifth and final chapter is dedicated to environmental protection.

Program

Chapter I: Introduction to the Concept of the Environment 2 weeks

Chapter II: The Concept of Sustainable Development 2 weeks

Chapter III: Environment and Resources 4 weeks

Chapter IV: Substances 4 weeks

Chapter V: Environmental Protection 3 weeks

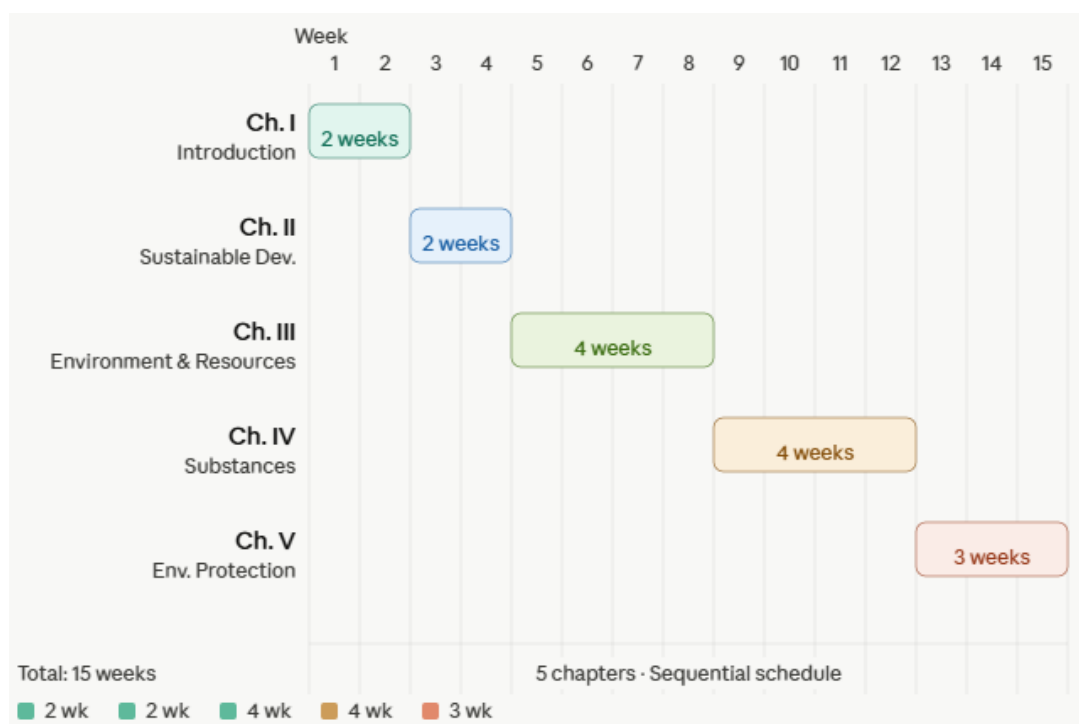


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Chapter I: Introduction to the Concept of the Environment



I.1. Objectives of Chapter I

This chapter provides students with fundamental knowledge of environmental concepts and fosters awareness of the effects of human activities and industrial development on ecology, ecosystems, and the environment. It further highlights the importance of environmental protection and socioeconomic stability as key components of sustainable development.

I.2. Introduction

Environmental issues have become one of the most pressing global challenges of the modern era and are the subject of extensive scientific investigation. Rapid population growth, industrialization, urban expansion, and the intensive exploitation of natural resources have significantly increased pressure on the environment, resulting in various forms of pollution and ecosystem degradation. Consequently, the protection of the environment has emerged as a priority for governments, international organizations, and scientific communities worldwide.

The growing awareness of environmental concerns led to the organization of the United Nations Conference on the Human Environment in Stockholm in 1972, which marked a turning point in international environmental policy. The conference established fundamental principles and adopted a comprehensive action plan aimed at addressing environmental degradation and promoting sustainable resource management. This initiative laid the foundation for the development of the concept of sustainable development, which was formally introduced in the early 1980s and later gained global recognition during the United Nations Conference on Environment and Development (Earth Summit) held in Rio de Janeiro in 1992.

Ecology

The term ecology was coined in 1866 by the German biologist Ernst Haeckel. Derived from the Greek words *oikos* (meaning “house” or “habitat”) and *logos* (meaning “study” or “science”), ecology is the branch of biology that examines the relationships between living organisms and their physical, chemical, and biological environments. It seeks to understand how organisms interact with one another and with the ecosystems in which they live.

Biocenosis

Biocenosis, also known as a biological community, refers to the assemblage of living organisms including microorganisms, plants, and animals that coexist within the same habitat and interact through various ecological relationships.

Ecosystem

An ecosystem is a dynamic and functional ecological unit composed of a community of living organisms (biocenosis) and the abiotic environment (biotope) in which they exist. The continuous interactions between biotic and abiotic components enable the flow of energy and the cycling of matter, thereby maintaining ecosystem structure and function.

Biotope

A biotope is the physical and environmental setting occupied by a biological community. It is characterized by relatively uniform ecological conditions, including climatic, geological, hydrological, and physicochemical factors such as temperature, humidity, soil composition, and water availability, which collectively determine the distribution and survival of living organisms.

I.3. Definition of the Environment

The word environment comes from the English term “environment,” meaning surroundings. Since the 1970s, it has been used to describe the global ecological context.

The environment refers to the totality of natural, social, cultural, and economic conditions that surround and influence living organisms and human activities. It includes both biotic components (plants, animals, microorganisms) and abiotic components (air, water, soil, climate, and natural resources), as well as human-made elements such as buildings, infrastructure, and institutions.

A commonly accepted definition is:

The environment is the set of physical, biological, and social factors that interact with and affect the life, development, and well-being of organisms and human societies.

This concept emphasizes the interconnected relationship between humans and their surroundings, where changes in one component can influence the entire environmental system.

I.3.1. General definition of the Environment

More generally, the environment is considered to be the set of factors that influence the surroundings of human beings. This definition places humans at the center of civilization. A much broader concept of the environment concerns the protection of the natural environment, land use planning, and the protection of natural or historical sites.

1.3.2. Legal Definition of the Environment

Definition in European legal texts: The European Directive defines the environment as:

“The set of elements which, in the complexity of their relationships, constitute the framework, surroundings, and living conditions of human beings, as they exist or as they are perceived.”

In Algeria: Algerian legislation defines the environment in Law No. 03-10 of 19 July 2003 as follows: “The abiotic and biotic natural resources such as air, the atmosphere, water, soil and subsoil, fauna and flora, including genetic heritage, the interactions among these resources, as well as natural sites, landscapes, and monuments.”

This legal definition highlights both the natural components of the environment and the relationships that exist between them.

I.4. History of the Environment

The concept of nature evolved significantly during the twentieth century thanks to the development of ecology as a scientific discipline. On March 19, 1902, the first international convention for the protection of wildlife species was signed. This was followed by the First International Congress for Nature Protection in Paris in 1923 and the London Convention on the Conservation of Fauna and Flora in their Natural State in Africa in 1933.

In 1948, the modern international commitment of states to environmental protection truly began with the creation of the International Union for Conservation of Nature. This organization marked one of the first global efforts to coordinate action for the conservation of nature and biodiversity at an international level.

During the 1960s, environmental awareness increased significantly across many countries. This period saw the emergence of the first ecological political movements and parties, influenced by scientific studies highlighting environmental degradation, pollution, and the loss of biodiversity. Media coverage also played an important role in bringing environmental issues to public attention, helping to shape environmental policies and public opinion.

A major milestone was the first United Nations Conference on the Human Environment, held in Stockholm, Sweden, from June 5 to 16, 1972. This conference represented the first global meeting focused specifically on environmental protection and sustainable development. It led to increased international cooperation and the creation of environmental programs within the United Nations system.

Following this important event, June 5 was designated as World Environment Day, which is now celebrated every year worldwide to raise awareness and encourage action for environmental protection.

The Earth Summit on Environment and Development, held in Rio de Janeiro, Brazil, in 1992, marked a major milestone in global environmental governance. It was during this conference that the

concept of sustainable development was officially adopted at the international level. This concept refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

The Rio Summit also led to the establishment of a long-term international cooperation framework through the United Nations Framework Convention on Climate Change. This convention created a system of annual meetings known as the Conference of the Parties (COP), where countries that signed the agreement regularly gather to assess progress and negotiate new commitments to combat climate change.

The first COP meeting (COP1) was held in Berlin in 1995, marking the beginning of structured global climate negotiations.

Following this, the Earth Summit +5, held in New York in June 1997, served as a review meeting to evaluate progress since the Rio Conference. During the same period, one of the most important international climate agreements, the Kyoto Protocol, was adopted. This protocol introduced legally binding targets for developed countries to reduce greenhouse gas emissions, representing a significant advancement in global efforts to address climate change.

I.5. Human Impact on the Environment

Human impact on the environment (or anthropogenic impact) refers to the alterations caused by human activities to biophysical environments, ecosystems, biodiversity, and natural resources. As the global population expands, the strain on Earth's finite systems accelerates, resulting in both direct and indirect ecological feedback loops.

I.5.1. Human impact on the ecosystem

An ecosystem is a community of living organisms (plants, animals, microorganisms) interacting with each other and with their physical environment (air, water, soil). Human activities strongly affect these natural systems, often disrupting their balance.

One major impact is the alteration or destruction of habitats. Through agriculture, urban expansion, mining, and infrastructure development, humans convert natural areas into human-dominated landscapes. This leads to fragmentation of habitats, making it difficult for species to survive, reproduce, or migrate.

A key consequence is Biodiversity Loss. When habitats are destroyed or degraded, many species decline or become extinct. This reduces the stability of ecosystems, since each species plays a role in maintaining ecological balance.

Another major impact is Pollution, which affects air, water, and soil within ecosystems. Chemicals, plastics, and waste products can poison organisms, disrupt food chains, and reduce ecosystem productivity. For example, water pollution can kill aquatic life, while air pollution can damage plants.

Human-driven Climate Change also affects ecosystems worldwide. Rising temperatures and changing rainfall patterns force species to adapt, migrate, or die. Many ecosystems, such as coral reefs and Polar Regions, are especially vulnerable.

Overexploitation of natural resources is another important factor. Overfishing, hunting, and excessive logging remove species faster than they can recover, weakening ecosystem stability and resilience.

Additionally, the introduction of invasive species through human trade and travel can disrupt ecosystems. These species often outcompete native organisms, changing food webs and reducing biodiversity.

In summary, human activities disturb ecosystems by destroying habitats, polluting environments, altering climate conditions, and reducing biodiversity. Protecting ecosystems requires sustainable resource use and conservation efforts.

I.5.2. Human Impact on the Atmospheric Environment (Air Pollution)

Air pollution is not a new phenomenon but has existed for centuries volcanic eruptions, dust carried by winds, forest fires however; pollution intensified from the 18th century onwards and continues to this day. It is now widely recognized that the intensification of motorized traffic and road transport has a direct consequence of worsening atmospheric pollution. Road traffic is particularly implicated through the emission of pollutants such as nitrogen oxides (NO_x), hydrocarbons (HC), and carbon monoxide (CO).

Furthermore, the media echoes concerns about global warming and climate change due to the large quantities of greenhouse gases emitted into the atmosphere. The hole in the ozone layer, caused by the release of volatile organic compounds, has been widely covered by the press, radio, and television. Alerts regarding ozone concentrations in cities during the summer period raise public awareness of this notion of air pollution, which is generated, most of the time, by industrial, agricultural, or domestic activities.

I.5.3. Human Impact on Soil (Soil Pollution)

Soil pollution refers to the contamination of soil with substances that alter its physical, chemical, or biological properties, rendering it harmful to living organisms and disrupting ecosystem functioning.

□ Main Sources of Soil Pollution:

1. Agricultural Activities

- Pesticides and herbicides (e.g., DDT, glyphosate) accumulate in soil and persist for years
- Synthetic fertilizers (nitrates, phosphates) cause chemical imbalances and leaching
- Irrigation with contaminated water introduces heavy metals and pathogens
- Plastic mulch films leave microplastic residues

2. Industrial Activities

- Heavy metal discharge (lead, cadmium, mercury, arsenic) from mining and smelting
- Hydrocarbons and solvents from petrochemical plants
- Acid rain from industrial emissions (SO₂, NO_x) lowers soil pH

3. Urban and Domestic Sources

- Household waste and landfills release leachates into surrounding soil
- Sewage sludge applied to fields may contain heavy metals and pathogens
- Construction materials (asbestos, paint) contaminate urban soils
- Fuel spills and exhaust deposits (lead from leaded petrol era, PAHs)
- Road salt (de-icing) alters soil salinity and ion balance

5. Radioactive Contamination

- Radioactive fallout from nuclear tests or accidents (e.g., Chernobyl)
- Unexploded ordnance and heavy metals from military operations

I.5.4. Human Impact on Water and Aquatic Environments:

Water covers about 71% of Earth's surface and supports nearly all life on the planet. Yet human activities have profoundly altered aquatic ecosystems from the smallest freshwater streams to the open ocean. Here is an overview of the major ways humans affect water and aquatic environments.



1.5.4.1. Human Impact on Water Resources and the Aquatic Environment

Water pollution and the degradation of marine environments, particularly in coastal areas, are primarily attributable to human activities through several major pathways:

- ☐ Discharge of Urban Wastewater

The release of domestic and municipal wastewater into natural environments introduces pathogens, excess nutrients, and micropollutants, including pharmaceuticals and detergents.

- ☐ Pollution of Rivers and Streams

Agricultural and industrial activities along riverbanks contribute to the contamination of watercourses, which subsequently transport pollutants to estuaries and coastal marine environments.

- ☐ Air Pollution

Many human activities produce air pollutants that eventually reach the oceans. Maritime transport releases hydrocarbons, sulfur compounds, and particulate matter into the atmosphere. Offshore gas extraction also generates gaseous emissions and can cause oil spills. Similarly, offshore oil extraction is a source of oil slicks and chronic pollution of marine environments.

- ☐ Effects of Pollution on Aquatic Ecosystems

This pollution affects the functioning and balance of all aquatic ecosystems, with impacts that occur at several levels. Aquatic fauna is particularly affected, experiencing increased mortality, endocrine disruption, and the bioaccumulation of toxic substances. Marine flora is also impacted, with the gradual destruction of seagrass beds, mangroves, and coral reefs. From a biogeochemical perspective, the nitrogen and phosphorus cycles are disrupted, promoting the occurrence of eutrophication. The physicochemical balance of aquatic environments is also altered, particularly through changes in pH, temperature, and

salinity. Finally, coastal areas undergo significant habitat degradation, with harmful consequences for the organisms that live there.

In conclusion, human activities are the main factor contributing to the degradation of aquatic environments. In light of this situation, integrated water resource management, combined with strict regulation of pollutant discharges, is an absolute necessity for the protection and preservation of these ecosystems, which are essential to life.

I.6. Demography: A Scapegoat?

The term “demography” is closely linked to the scapegoat phenomenon in political sociology and demography, particularly during periods of economic or social crisis. In such contexts, certain groups within the population structure are instrumentalized and held responsible for collective failures.

The Interaction between Demography and the Scapegoat Phenomenon in times of crisis, some societies deliberately designate specific ethnic or religious groups as scapegoats in order to divert the frustrations that have accumulated within the population. Immigrants and foreign workers are frequently blamed for unemployment or economic difficulties, thereby serving to conceal the shortcomings of government policies. Age groups are not spared either: a rapidly growing youth population may be associated with rising crime rates, while older people are sometimes portrayed as a burden on healthcare systems. This practice of identifying demographic groups as responsible for social problems generates increasing polarization within society, deepening divisions and eroding trust among the various segments of the population.

Chapter II: The Concept of Sustainable Development



II.1. Objectives of Chapter II

The purpose of this chapter is to provide a historical perspective on the concept of sustainable development by examining its objectives, including the role of international organizations, national governments, and industries, as well as its environmental implications and challenges.

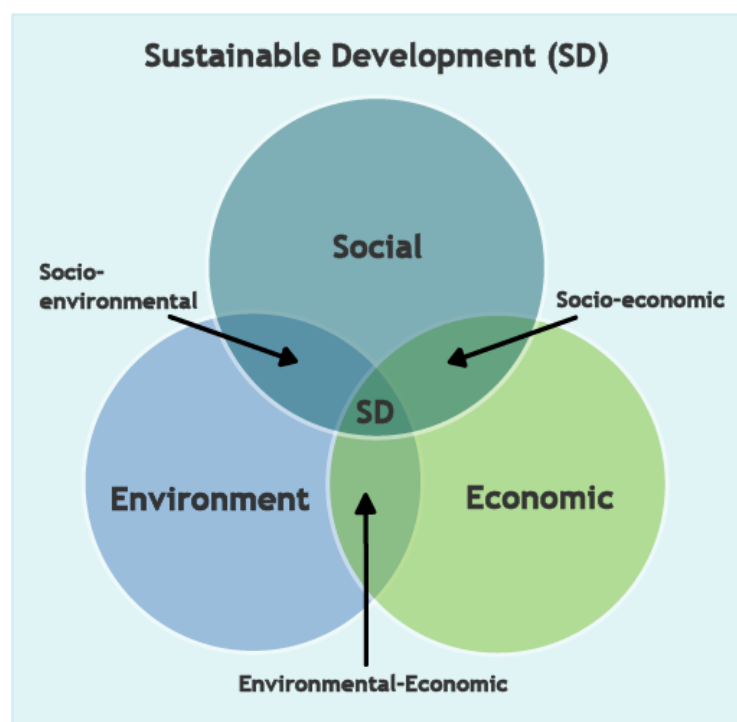
II.2. Introduction

The term development generally refers to growth, improvement, or progress in a particular field, whether economic, industrial, social, or related to human activities in general. Sustainable development seeks such progress while preserving nature, biodiversity, and essential resources for the long term.

The concept is based on development that is:

- Environmentally sustainable
- Socially equitable
- Economically viable

Although the expression “sustainable development” became widely used in the 1970s, its principles gained real importance during the 1980s due to the depletion of natural resources, increasing pollution, population growth, poverty, unemployment and other socioeconomic challenges.



II.3. Definition of Sustainable Development

The Brundtland Report in 1987 defines sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

Sustainable development corresponds to the duties of current generations to pass on a livable, viable, and reproducible world. The concept of “needs”, and more particularly the essential needs of the most disadvantaged, to whom the greatest priority should be given, and the idea of the limitations that the state of our technology and social organization imposes on the capacity of the environment to meet current and future needs.

A need is, for living beings, a feeling of lack, deprivation, or dissatisfaction that drives them to perform acts perceived as necessary, or even indispensable. The purpose of these acts is to eliminate this feeling of lack: the satisfaction of the need. Classifications, which always have a subjective character, make it possible to distinguish several classes of needs, such as:

- ☐ Primary or organic (physiological) needs necessary for survival (breathing, eating, drinking, sleeping, etc.);
- ☐ Secondary needs, which have a qualitative and psychological dimension and whose non-fulfillment is not vital (loving and being loved, knowing, giving meaning);
- ☐ Fundamental needs, which correspond to the needs to exist and to philosophize or to ask existential questions.



Figure II.1. The Three Pillars of Sustainability

II.4. History of Sustainable Development

The origins of sustainable development are closely linked to international cooperation efforts following World War II.

In 1942, Franklin Roosevelt and Winston Churchill drafted the Atlantic Charter, outlining principles for peace and international cooperation. This initiative contributed to the creation of the United

Nations (UN) and several specialized agencies, including:

- FAO – Food and Agriculture Organization
- WHO – World Health Organization
- UNESCO – United Nations Educational, Scientific and Cultural Organization

By 1965, numerous international institutions were working on development and humanitarian assistance, including UNICEF, the World Food Program (WFP), and the United Nations Development Program (UNDP).

The first ideas related to sustainable development emerged in the early 1970s under the United Nations Environment Program (UNEP), which promoted the concept of “Ecodevelopment.” This approach emphasized the satisfaction of fundamental human needs such as housing, food, energy, water, education, and healthcare.

Major milestones included:

- United Nations Conference on the Environment (1972) The Economic and Social Council recommended in 1968 that the General Assembly consider and convene a United Nations conference on the problems of the human environment. In 1972, the United Nations Conference on the Environment held in Stockholm was the first world conference to make the environment a major issue. Participants adopted a series of principles for the environmentally sound management of the environment, including the Stockholm Declaration, the Action Plan for the Environment, and several resolutions.
- World Food Conference, Rome (1975)
- United Nations Conference on Desertification, Nairobi (1977)
- International Conference on Science and Technology for Development, Singapore (1978)

In 1980, the International Union for Conservation of Nature (IUCN) formally introduced the notion of sustainable development in its World Conservation Strategy

In 1983, the United Nations established the World Commission on Environment and Development, chaired by Gro Harlem Brundtland. After four years of extensive research, the commission delivered a landmark report to the General Assembly in 1987 titled Our Common Future and widely known as the Brundtland Report which placed sustainable development at the center of the global agenda.



United Nations Conference on Environment and Development (1992)

Convened under a United Nations General Assembly resolution dated December 20, 1988, the conference was held in Rio de Janeiro from June 3 to 14, 1992. Originally known as the "Earth Summit", it was later referred to as the Rio Conference. The event led to the establishment of the Commission on Sustainable Development and resulted in the adoption of three major agreements.

The conference resulted in the adoption of three major agreements. The Rio Declaration on Environment and Development established a set of principles defining the rights and responsibilities of States toward the environment. Complementing this, Agenda 21 provided a comprehensive global action plan aimed at promoting sustainable development across all sectors. Finally, the Forest Principles laid out a framework of guidelines intended to serve as a foundation for the sustainable management of forests worldwide.

This conference is followed by others: The United Nations Conference on Population and Development in Cairo in 1994. The United Nations Conference on Poverty and Social Development in Copenhagen in 1995.

The New York Summit in 1997, still pursuing the same context of biodiversity and the climate domain (the problem of global warming), which prompted another assembly the same year in

Tokyo in December 1997, addressing climate issues by signing commitments on the reduction of greenhouse gas emissions. World Summit on Sustainable Development (2002) Rio+10.

Convened by the UN General Assembly through Resolution 55/199 of December 20, 2000, this summit also known as Rio+10 was held in Johannesburg from August 26 to September 4, 2002. It reviewed the

progress made in implementing Agenda 21 since its adoption in 1992, assessing how far the international community had come in meeting its sustainable development commitments.

The summit also called for negotiations, within the framework of the Convention on Biological Diversity (CBD), to establish an international regime aimed at promoting and protecting the fair and equitable sharing of benefits arising from the use of genetic resources a measure intended to advance the CBD's third objective. UN Conference on Sustainable Development Rio+20 (2012) UN Conference on Sustainable Development Rio+20 (2012).

Twenty years after the original Earth Summit, world leaders reconvened in Rio to renew their commitment to sustainable development. Despite notable human progress longer lifespans, lower mortality rates, and greater empowerment of marginalized groups the global population had swelled by 1.5 billion, poverty remained widespread, and environmental conditions had deteriorated significantly. Climate change, biodiversity loss, land degradation, and freshwater scarcity had all worsened, while globalization's benefits remained unevenly distributed.

The 2012 Rio+20 Conference sought to reassess progress, address these growing gaps, and refocus international efforts around the three pillars of sustainable development: economic growth, social equity, and environmental protection.

II.5. Main Principles of Sustainable Development

The Rio Declaration emphasized, in its Article 28, the essential role that falls to territories and local communities in matters of sustainable development. Thus, at each level of local authority, lies the responsibility to develop, for its territory, and to implement a program of action in accordance with the principles of Agenda 21. Sustainable development involves many actors: researchers, citizens, associations, states and public authorities, international organizations, as well as businesses and trade unions.

Sustainable development aims to translate into policies and practices a set of 27 principles, outlined at the Rio Conference in 1992. Among these principles: The 10 founding principles of sustainable development:

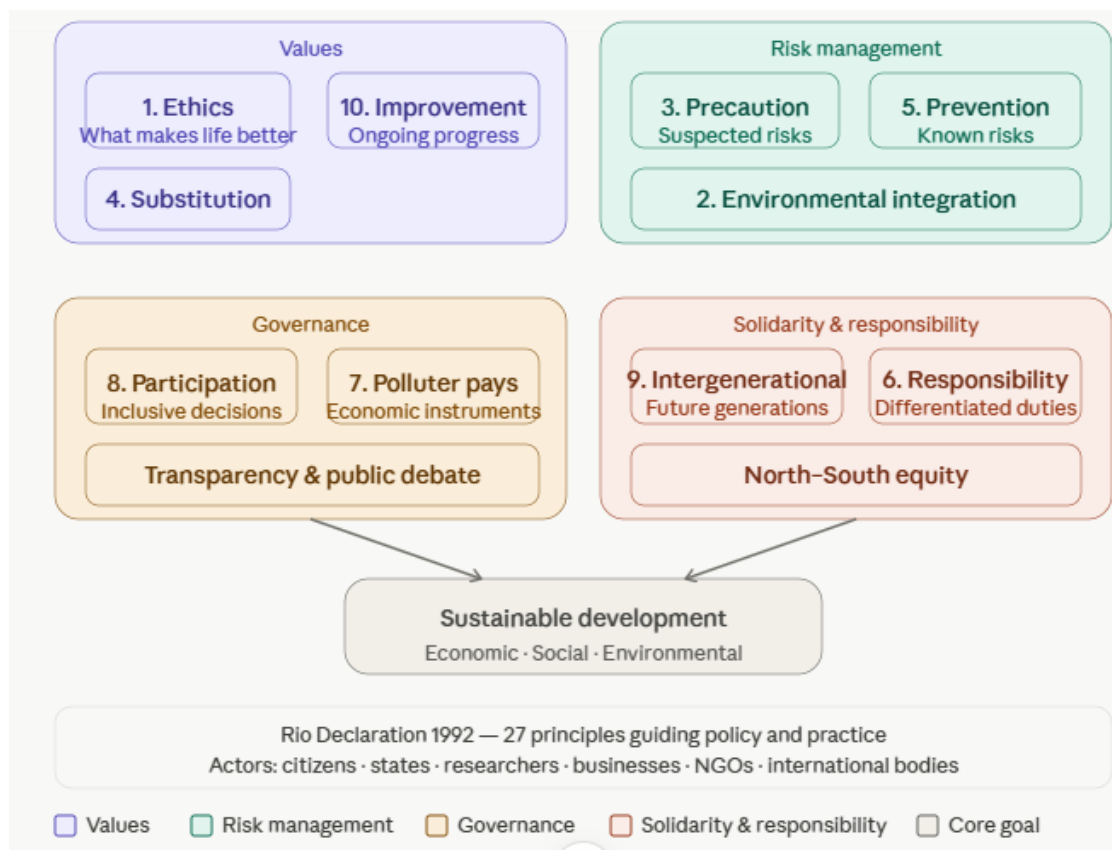


Figure II.2. Ten founding principles of sustainable development

- 1- The principle of ethics.
- 2- The principle of integrating environmental protection.
- 3- The precautionary principle with regard to the environment.
- 4- The principle of substitution.
- 5- The principle of prevention.
- 6- The principle of international responsibility and solidarity.
- 7- The 'polluter pays' principle.
- 8- The principle of participation and transparency.
- 9- The principle of intergenerational solidarity.
- 10- The principle of continuous improvement.

Core Principles of Sustainable Development Ethics

1. Ethics

Ethics reflects on behaviors that make the world better or more livable — the same goal as sustainable development, which balances wealth creation with social equity and environmental responsibility.

2. Prevention

States must coordinate efforts to prevent transferring harmful activities or substances to other countries that could cause serious environmental damage or health risks.

3. Precautionary Principle

When serious or irreversible environmental damage is possible, lack of scientific certainty cannot justify inaction. Precaution targets suspected risks; prevention manages known ones.

4. Participation & Transparency

Decision-making must be inclusive, transparent, and pluralistic — involving all relevant stakeholders from local to international levels through consultation and public debate.

5. Intergenerational Solidarity

Present decisions must account for future generations' needs and their right to a healthy environment, as well as global equity between North and South, rich and poor, urban and rural areas. The 0.7% GDP target for development aid remains largely unmet, averaging only 0.3%.

6. Responsibility

Shared but differentiated — developed nations bear greater responsibility for environmental degradation and must lead in reducing emissions. This principle also underpins the polluter-pays and damage reparation principles.

7. Polluter Pays

Those who cause pollution should bear its costs, promoting environmental protection through economic instruments without distorting international trade.

8. Integrating Environmental Protection

This principle establishes that environmental concerns must not be treated as an afterthought or a separate domain they must be built into every decision from the very beginning, at every level: economic, social, legislative, and spatial planning.

9. The Principle of Substitution

This principle holds that whenever a dangerous, polluting, or environmentally harmful product, substance, or process exists, it must be replaced substituted by a less dangerous or less harmful alternative, as soon as one is technically and economically feasible.

10. The Principle of Continuous Improvement

This principle holds that sustainable development is not a fixed destination to be reached, but an ongoing process of progress. Actors states, businesses, local authorities, organizations must continually evaluate their practices, set higher standards over time, and never consider the work "done." The underlying logic is one of iterative advancement: each achievement becomes the new baseline from which further improvement is measured.

II.6. Sustainable Development Goals



In September 2015, the United Nations adopted 17 Sustainable Development Goals (SDGs), forming the Agenda 2030 framework.

These goals include:

Goal 1: End poverty in all its forms everywhere

Goal 2: End hunger, achieve food security, improve nutrition and promote sustainable agriculture

- Goal 3: Ensure healthy lives and promote well-being for all at all ages
- Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- Goal 5: Achieve gender equality and empower all women and girls
- Goal 6: Ensure availability and sustainable management of water and sanitation for all
- Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 10: Reduce inequality within and among countries
- Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12: Ensure sustainable consumption and production patterns
- Goal 13: Take urgent action to combat climate change and its impacts
- Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development
- Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
- Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
- Goal 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development.

II.7. Environmental Challenges of Sustainable Development

Sustainable development sits at a difficult crossroads with the environment here's a breakdown of the six core challenge areas:

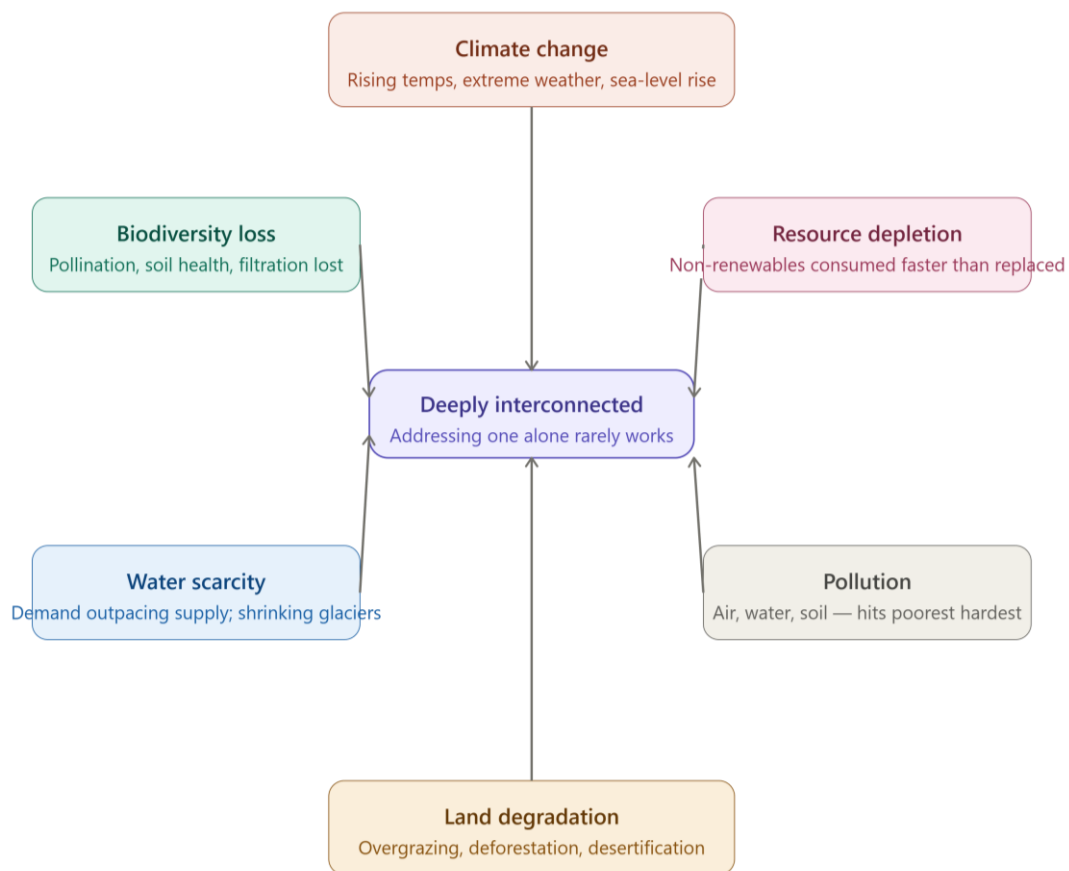


Figure II.3. Environmental Challenges diagram

1. Climate change is the defining challenge. Rising greenhouse gas concentrations drive temperature increases, sea-level rise, and more frequent extreme weather events, disrupting agriculture, infrastructure, and ecosystems that development depends on.

2. Biodiversity loss quietly undermines the natural systems that economies rely on pollination, soil health, water filtration. Habitat destruction (often from development itself) and invasive species have pushed extinction rates far above natural background levels.

3. Resource depletion creates a fundamental tension: many forms of development consume non-renewable resources (fossil fuels, rare minerals, and old growth forests) faster than alternatives can be scaled. This locks in dependency on what must eventually run out.

4. Pollution in its many forms industrial emissions, agricultural runoff, plastic waste degrades the air, water, and soil that human health and food production depend on. It often hits the poorest communities' hardest, worsening inequality.

5. Water scarcity is accelerating as demand from agriculture, industry, and growing cities outpaces supply. Climate change intensifies this through altered rainfall patterns and shrinking glaciers the "water towers" of many river systems.

6. Land degradation through unsustainable farming, overgrazing, and deforestation strips topsoil and pushes toward desertification, reducing the productive land available for both food and ecosystems.

A critical complication is that these challenges are deeply interconnected climate change accelerates water scarcity and land degradation; deforestation drives both biodiversity loss and climate change; pollution reduces agricultural productivity. Addressing one in isolation rarely works. Sustainable development frameworks, like the UN's SDGs, aim to tackle them together. Simple actions by individuals can significantly improve quality of life and support sustainable development objectives.

Chapter III: Environment and Resources



III.1. Introduction

Since the dawn of humanity, natural resources have formed the foundation of life on Earth. They play a crucial role in the well-being of populations and are a major factor in the economic development of nations. Throughout history, competition for access to valuable natural resources has often been a cause of conflicts and territorial expansion.

However, the future of humanity and the planet is increasingly threatened by economic development policies based on the overexploitation of natural resources. Such practices contribute significantly to environmental degradation. Consequently, environmental regulations and sustainable management strategies have been developed to ensure the rational use of natural resources while respecting environmental standards. This objective is one of the central pillars of sustainable development.

III.2. Definition of Natural Resources

Natural resources are all goods and materials that originate from nature without direct human intervention. They are essential to the social and economic development of humanity, providing the raw materials, energy, food, and environmental services necessary for life. Natural resources can be defined as products of biological, ecological, or geological processes that satisfy human needs. They encompass tangible materials such as wildlife species, soils, minerals, timber, and water as well as ecosystem services that are vital for economic production and the sustenance of life. This concept reflects the diverse, and often competing, ways in which societies assign value to the utility of the biophysical world.

III.3. Types of Natural Resources

Natural resources are generally classified into two main categories:

- Renewable natural resources
- Non-renewable natural resources

III.3.1. Renewable Natural Resources

Renewable natural resources are resources that can be naturally replenished over time through ecological or atmospheric processes. They are natural assets whose reserves can be regenerated if properly managed, ensuring their long-term availability for future generations. Common examples include sunlight, wind, water, forests, and soil.

III.3.1.1. Water



Figure III.1. Water

Water (H_2O), composed of two hydrogen atoms and one oxygen atom, is one of the most essential compounds for life on Earth, covering approximately 71% of the planet's surface. Its unique properties including its high polarity, which makes it an excellent solvent; its strong hydrogen bonding, which contributes to its relatively high boiling point and surface tension; and its lower density in the solid state than in the liquid state make it unique among common substances. While salt water accounts for about 97.5% of Earth's total water reserves, only about 2.5% is fresh water, much of which is stored in ice caps, glaciers, and underground aquifers. Biologically, water forms the basis of all bodily fluids, representing about 63% of adult human body weight, and enables essential cellular functions. In agriculture, water is used for irrigation and supports global food production. From an environmental perspective, the continuous water cycle through evaporation, condensation, and precipitation helps regulate Earth's climate and maintain ecosystem balance. Water is considered a renewable resource because it is continually replenished through the hydrological cycle, although its availability varies by region and can be affected by climate and human activities.

III.3.1.1.1. The Water Cycle

The water cycle describes the continuous movement of water through different physical states (liquid, solid, and gas) and includes four main stages:

1. **Evaporation:** Solar energy causes water from oceans, lakes, rivers, and other water bodies to change from liquid to water vapor. Water released by plants through their leaves is called evapotranspiration.
2. **Sublimation:** In cold regions, snow and ice can change directly from a solid to water vapor without becoming liquid first. This process is promoted by dry air, low humidity, and low atmospheric pressure.
3. **Condensation:** As water vapor rises, it cools and condenses into tiny water droplets or ice crystals, forming clouds. Condensation occurs when air reaches its dew point.

4. Precipitation: When cloud droplets become large and heavy enough, they fall to Earth as rain, snow, sleet, or hail, depending on atmospheric conditions.
5. Infiltration: Some precipitation seeps into the ground, replenishing soil moisture and groundwater reserves, including aquifers.
6. Runoff: Water that does not infiltrate flows over the land surface into streams, rivers, lakes, and oceans under the influence of gravity.

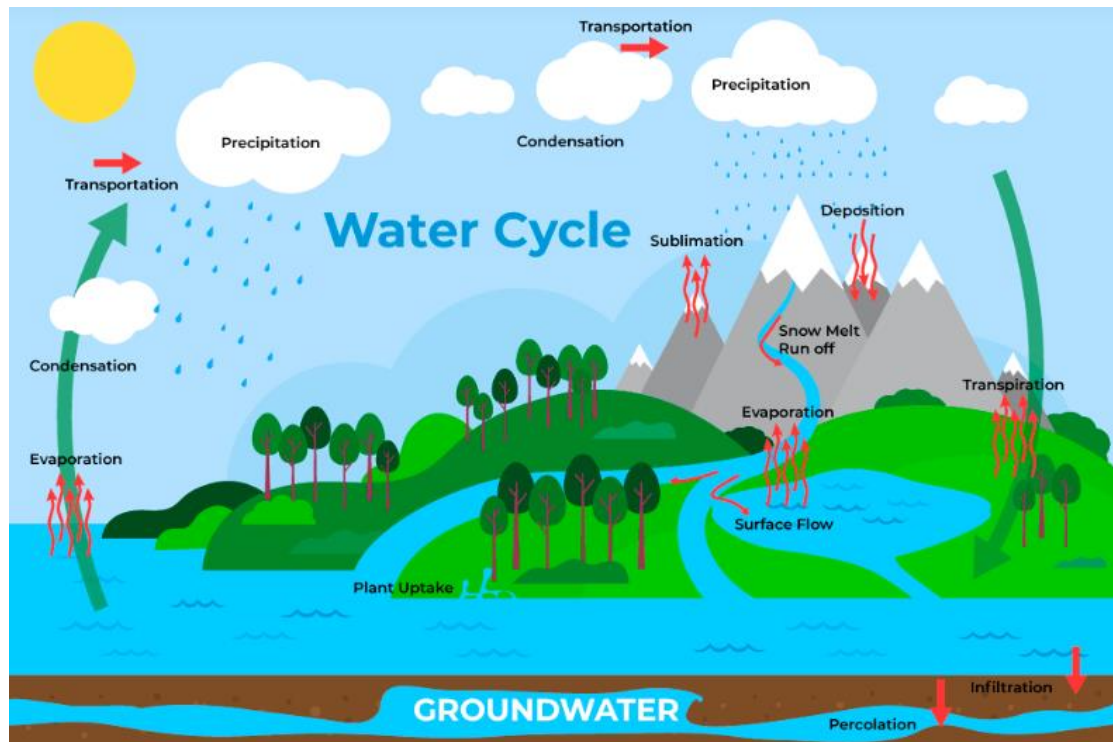


Figure III.1. Water cycle (internet source).

III.3.1.1.2. Human Influence on the Water Cycle

Human activities severely disrupt the natural water cycle. Deforestation removes trees that absorb rainfall and stabilize soil, increasing runoff and reducing groundwater recharge. Urban expansion replaces permeable surfaces with concrete, accelerating flooding and limiting infiltration. Industrial development withdraws massive water volumes, often returning it polluted or thermally altered, harming aquatic ecosystems. Agricultural chemicals and sewage contaminate both surface and groundwater. Acid rain, formed from atmospheric pollutants, acidifies lakes and leaches heavy metals into waterways. Together, these pressures reduce water availability and resilience to droughts and floods.

III.3.1.2. Air and the Atmosphere

The atmosphere surrounds the Earth, holding the air we breathe, protecting us from outer space, and

containing moisture (clouds), gases, and tiny particles. It acts as a gaseous envelope essential to all life on Earth. Dry air is a surprisingly consistent mix of gases, though water vapor (ranging from 0–4% depending on location and climate) and trace pollutants can vary. The primary components are:

Nitrogen (78%): Acts as a buffer that dilutes oxygen and prevents rapid burning.

Oxygen (21%): Essential for the respiration of nearly all living things and for combustion.

Remaining 1%: Consists mostly of Argon (0.9%), with Carbon Dioxide (0.04%) and trace amounts of neon, helium, and methane. Carbon dioxide plays a critical role as a greenhouse gas, trapping heat and supporting plant photosynthesis. Methane, though present in smaller quantities, also acts as a significant greenhouse gas contributing to atmospheric warming.

III.3.1.2.1. Layers of the Atmosphere

The Earth's atmosphere is a gaseous envelope surrounding our planet, held in place by gravity. It extends approximately 1,000 kilometers, though no precise boundary separates it from outer space. While its three main gases nitrogen, oxygen, and argon remains proportionally constant at all altitudes, atmospheric mass decreases with height, with 95% concentrated below 20 kilometers.

The atmosphere is structured into five distinct layers.

The *troposphere* (0–12 km) is where weather phenomena and the greenhouse effect occur, with temperature decreasing with altitude.

Above it, the *stratosphere* (12–50 km) houses the ozone layer (25–30 km), which shields Earth from harmful solar radiation.

The *mesosphere* extends to around 80 km, where temperatures drop to -90°C and meteorites burn up, creating shooting stars.

The *thermosphere* is characterized by extremely low density but very high temperatures reaching 1,500°C. It hosts the International Space Station and is where auroras both boreal and austral are observed due to solar ionization.

Finally, the *exosphere* begins at around 800 km, gradually thinning until it merges seamlessly with outer space.

Together, these layers form a complex and vital shield supporting all life on Earth.

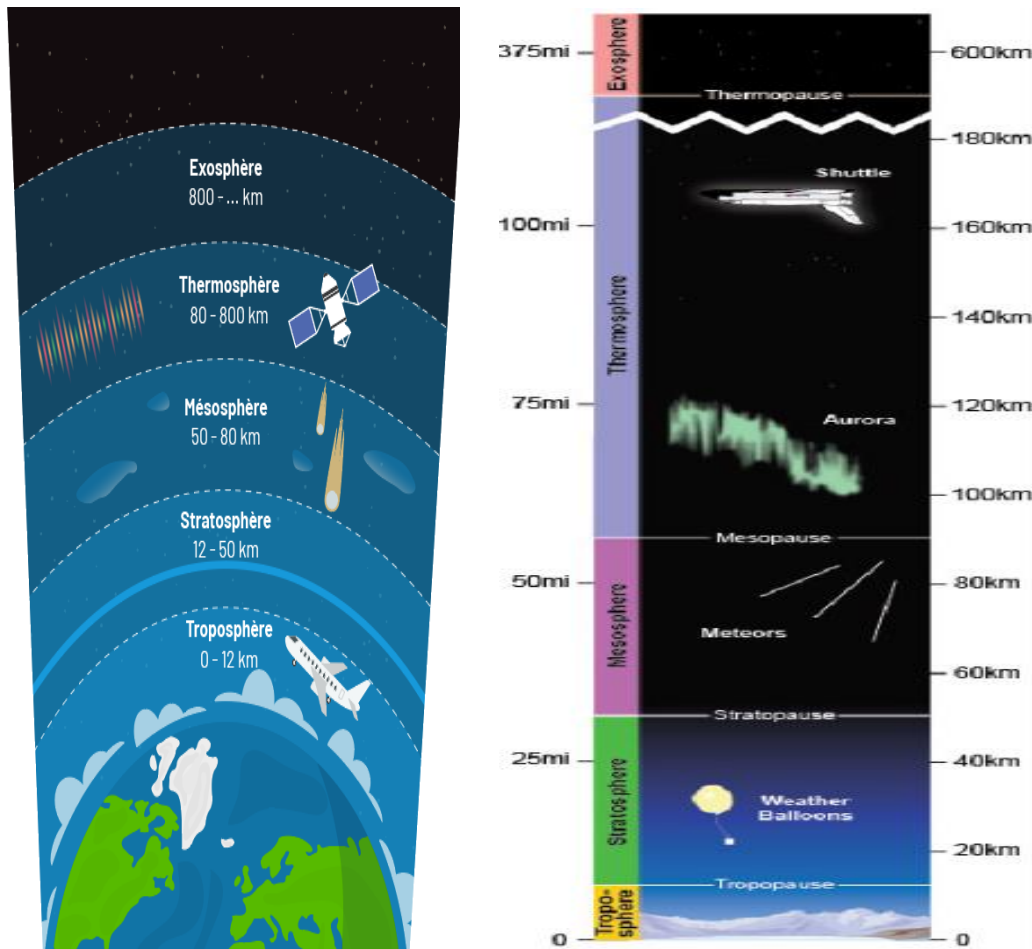


Figure III.1. Layers of atmosphere diagram

III.3.1.3. Land

Land encompasses all terrestrial elements above sea level, including soils, relief features, flora, and fauna. It plays a fundamental role in maintaining ecological balance, supporting agricultural and industrial development, and enabling the extraction of mineral and fossil resources. As such, land is an essential natural resource, serving as both a foundation for life and a basis for human development.

III.3.1.4. Forests

Forests are among the most abundant and diverse natural resources, providing oxygen, timber, medicinal plants, shelter, and fuel. They combat desertification, reduce soil erosion, regulate climate, preserve biodiversity, and support socioeconomic development. However, forest ecosystems worldwide are increasingly threatened by deforestation, industrial activities, forest fires, and acid rain, putting both environmental balance and human well-being at serious risk.



Figure III.1. Forests

III.3.1.5. Soil

Soil is the living outer layer of the Earth's crust, acting as a complex ecosystem that supports plant growth, filters water, and recycles nutrients. It is composed of minerals, organic matter, air, and water. Its quality directly dictates agricultural productivity and ecosystem resilience.

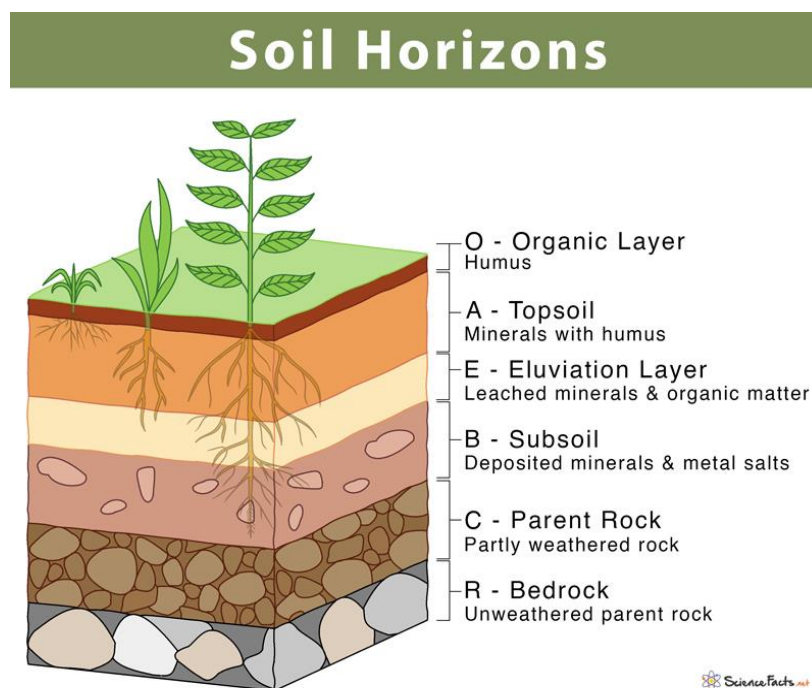


Figure III.1. Soil horizons

A mature soil profile is composed of six distinct layers, known as horizons, each identified by a letter: O, A, E, B, C, and R. Immature soils may lack some of these layers.

The *O* horizon, or organic layer, is the uppermost layer, rich in decomposed plant and animal matter, giving it a dark brown color.

Below it lies the *A* horizon, commonly known as topsoil or the humus layer. This is the most biologically active zone, containing the highest concentration of nutrients and hosting a wide variety of organisms such as earthworms, bacteria, and fungi. Its porous structure allows it to retain air and moisture, making it essential for seed germination and plant root development.

The *E* horizon, or eluviation layer, forms where clay, minerals, and organic matter have been leached downward, leaving behind sand, silt, and resistant materials like quartz. This layer is most common in forested soils.

Beneath it, the *B* horizon, or subsoil, accumulates minerals and metal oxides such as iron, aluminum, and calcium carbonate leached from upper layers. Though lower in organic content, it retains significant water due to its dense, clayey composition.

The *C* horizon, also called regolith or parent rock, consists of fragmented bedrock with no organic matter. It represents the transitional zone between the earth's inner layers and the upper soil horizons, and plant roots generally do not reach this depth.

III.3.1.6. Biodiversity

Biodiversity is the extraordinary variety of all life on Earth, from tiny microorganisms and genes to vast ecosystems. It functions as a complex, interconnected web where each living thing plays a vital role in keeping our planet resilient, cleaning our air and water, and regulating the climate.

Understanding the scope of global biological diversity requires looking at it through different, interconnected levels.

The Levels of Biodiversity

Genetic Diversity: The variation of genes within a single species. It acts as an insurance policy, allowing populations to adapt to changing environments, diseases, and climate shifts.

Species Diversity: The variety of different species within a specific region or across the planet. This spans plants, animals, fungi, and bacteria.

Ecosystem Diversity: The variety of different ecosystems such as deserts, forests, coral reefs, and wetlands and the complex interactions within them.

III.3.1.7. Food Resources

Food resources refer to the various biological and agricultural systems that sustain human life and

nutrition. They are broadly categorized into agricultural crops (like wheat and rice), animal husbandry (meat and dairy), and aquaculture/fisheries (seafood). Managing these resources sustainably is critical to global food security.

III.3.2. Non-Renewable Natural Resources

Non-renewable resources are finite materials that replenish naturally at a rate far slower than they are consumed. Once depleted, they are unavailable for human use on a human timescale. They primarily consist of fossil fuels (oil, coal, natural gas) and geological minerals (metal ores, uranium).

III.3.2.1. Minerals

Minerals are inorganic materials extracted from the Earth's crust. They are economically valuable and essential for industrial production, although mining activities often have significant environmental impacts.

III.3.2.2. Fossil Fuels

Fossil fuels originate from the decomposition of organic matter over millions of years. The main fossil fuels are:

- Coal
- Petroleum
- Natural gas

Coal is rich in carbon and remains one of the most abundant fossil energy sources.

Petroleum is a complex mixture of hydrocarbons and is one of the world's primary energy resources.

Petroleum products are used in transportation, plastics manufacturing, and numerous industrial processes.

Natural gas consists primarily of methane (CH₄) and is considered one of the cleaner fossil fuels. It plays an important role in electricity generation and industrial applications.

III.3.2.2.1. Nuclear Energy

Nuclear energy is produced through nuclear fission reactions involving heavy atomic nuclei such as uranium. Nuclear power plants generate large quantities of electricity and have become a major component of the global energy mix.

III.4. Renewable Energy Sources

Renewable energy production has expanded rapidly worldwide over recent decades, contributing to a major transformation of the global energy system.

Renewable energies are often referred to as clean energies because they are replenished naturally and generally produce lower environmental impacts than fossil fuels.

Major renewable energy sources include:

- Solar energy

- Wind energy
- Hydropower
- Geothermal energy
- Biomass energy
- Marine energy

III.4.1. Solar energy

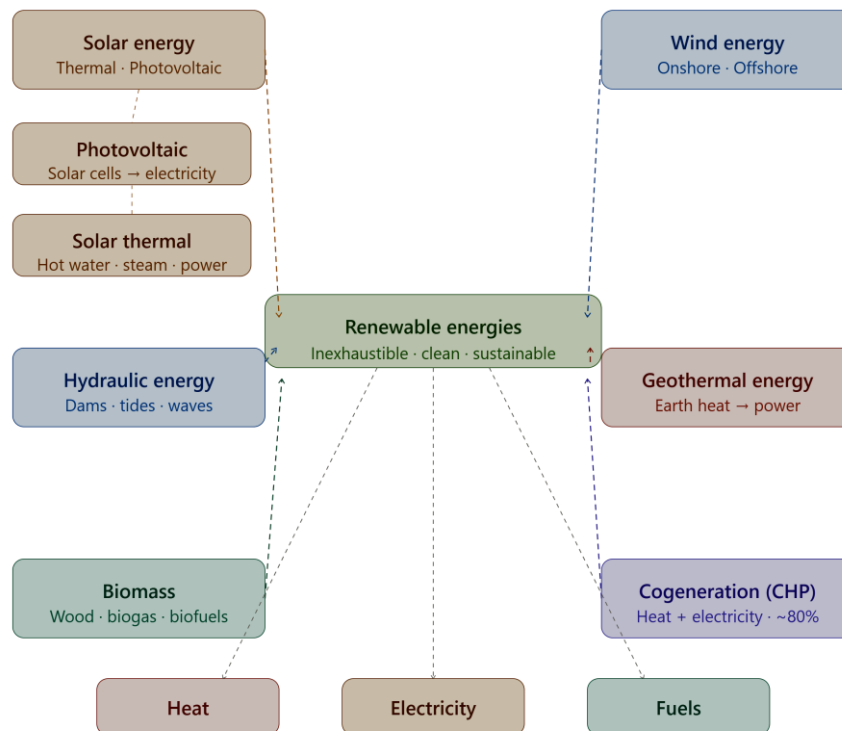


Figure III.1. Renewable energy diagram

Solar energy, transmitted by radiation, enables the production of heat and electricity through thermal solar panel systems and photovoltaic panels.

III.4.1.1. Photovoltaic Solar Energy

Photovoltaic solar energy is electrical energy produced by converting solar radiation using solar cells or modules that generate electricity.

III.4.1.2. Thermal Solar Energy

Solar collectors produce domestic hot water. They can also be used for heating. Solar collectors, also called "high temperature" collectors, produce electricity through steam as an intermediary.

III.4.2. Wind Energy

Wind energy comes from the kinetic energy of the wind. Known by its technical term, wind turbines (aerogenerators), set in motion by the wind and make it possible to produce electricity, both at sea (tidal/hydro energy) and on land.

Wind turbines, like all other renewable energies, produce no air or water pollution at their production site, although some criticize them for being too noisy or for affecting the landscape.

III.4.3. Hydraulic Energy

Hydraulic energy harnesses the power of water that is, the movement of water such as waterfalls, watercourses, marine currents (tidal energy), tides, and waves (wave energy) and, through dams or small power plants on watercourses, converts the kinetic energy of water movement into electricity.

III.4.4. Geothermal Energy

Geothermal energy is the use of heat derived from the temperature difference beneath the earth's surface to produce energy used for heating (low and medium energy) or to be converted into electrical energy (high energy).

III.4.5. Biomass Energy

Biomass is used to produce energy from organic materials such as wood, heat from waste incineration plants, and sludge from wastewater or industry that produces biogas (through methanization), which is then burned to generate heat or electricity and to produce biofuels.

III.4.6. Cogeneration or Combined Heat and Power Production

Cogeneration is a highly efficient system used in many industrial processes; it simultaneously produces two different forms of energy from a single fuel:

- Heat that can be used in many industrial processes instead of being released into the atmosphere, making it an energy source with major economic and environmental benefits.
- Electricity (or mechanical power)

Combined heat and power (CHP) systems achieve efficiencies of up to 80%, far exceeding the performance of conventional conversion systems, which are typically less than 35%.

Chapter IV: Substances



IV.1. Introduction

Environmental pollution is currently one of the major problems threatening the balance of life on Earth. It primarily affects human health and well-being, as well as all ecosystems. Unfortunately, human activities are the main source of environmental pollution and degradation, whether of the atmosphere, water, or soil, due to the pollutants generated by various socio-economic and industrial activities.

At present, most polluting substances are subject to environmental emission standards according to their lifespan and concentration.

IV.2. Atmospheric Pollutants

Pollution issues occur on very different spatial and temporal scales. For example, the lifetime of methane (CH_4) in the atmosphere is approximately 12 years, that of carbon monoxide (CO) is about 40 days, and sulfur dioxide (SO_2) remains in the atmosphere from a few days up to one month. However, the concentration of these substances varies depending on the location and its distance from the emission source.

Two types of pollutants can be distinguished:

- Primary pollutants: pollutants these are present at the point of their emission.
- Secondary pollutants: pollutants resulting from the physicochemical transformation of primary pollutants during their residence time in the atmosphere.

	Primary	Secondary
Origin	Emitted directly	Formed in the atmosphere
Example	SO_2 , CO , soot	Ozone(O_3), Sulfuric acid
Control	At the source	Harder to controle

IV.3. Different Types of Pollutants

IV.3.1. Regulated Pollutants

Currently there are 12 regulated pollutants in outdoor air and 2 in indoor air, given their effect on health and the environment, they are considered as indicators of atmospheric pollution and they are monitored by continuous measurements using specialized equipment, for outdoor air the measurements are

generally taken by organizations and associations for air quality monitoring such as sama safia in Algeria, the various regulated pollutants are:

- ☐ In Outdoor Air
 - **SO₂**: Sulfur dioxide
 - **CO**: Carbon monoxide
 - **NO_x**: Nitrogen oxides
 - **O₃**: Ozone
 - **PM₁₀**: Particulate matter
 - **PM_{2.5}**: Fine particulate matter
 - **C₆H₆**: Benzene
 - **Pb**: Lead
 - **As**: Arsenic
 - **Cd**: Cadmium
 - **Ni**: Nickel
- ☐ In indoor Air
 - **CH₂O**: Formaldehyde
 - **C₆H₆**: Benzene

IV.3.2. Organic Compounds

VOCs encompass a multitude of substances and do not correspond to a very rigorous definition. Hydrocarbons belong to VOCs and are often incorrectly conflated with them. This is undoubtedly due to the fact that VOCs are often expressed in total hydrocarbon equivalents of methane, or propane, or in relation to another reference hydrocarbon. It is common to distinguish separately methane (CH₄), which is a particular VOC naturally present in the air, from other VOCs, for which the notation NMVOC (Non-Methane Volatile Organic Compounds) is then used. Different families of VOCs can be distinguished, namely:

- Alkanes (propane)

- Alkenes (known for their high reactivity)
- dienes and terpenes (multiple and double bonds)
- Mono or polycyclic aromatics
- Oxygenated compounds (alcohols, ketones, esters...)
- Mono or polycyclic aromatics (benzene, toluene)

Sources of VOCs (Volatile Organic Compounds) are extremely numerous. Emissions arise from certain industrial processes involving the use of solvents (basic and fine chemicals, specialty chemicals, metal degreasing, paint application, printing, glues and adhesives, rubber manufacturing, etc.), as well as from processes that do not involve solvents (petroleum refining, the use of CFCs, the production of alcoholic beverages, bread making, etc.). The use of fuels in combustion systems contributes somewhat to VOC emissions, but to a much lesser extent than the proportions reported for SO₂ and NO_x. Transportation especially road traffic is among the leading sources of emissions. It should also be noted that biomass (particularly forests) is a significant emitter. In addition, emissions are associated with household products such as paints, cleaning products, perfumes and cosmetics, newspapers, tobacco, and others.

IV.3.3. Persistent Organic Pollutants (POPs)

Within the framework of the Stockholm Convention, which entered into force on May 17, 2004, 12 persistent organic pollutants (organic compounds that are toxic at low concentrations) were banned and their production and use were strictly limited, including insecticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, and toxaphene), a fungicide (hexachlorobenzene (HCB)), and chemical products resulting from the production of other chemical substances or from waste incineration (dioxins and furans (Diox) and a range of chlorinated hydrocarbons and Polycyclic Aromatic Hydrocarbons (PAHs)), as well as other products used in industrial applications such as plastic additives (Polychlorinated Biphenyls PCB), Trichloroethylene (TRI), Trichloroethane (TCE), and Tetrachloroethylene (PER).

These are products of industrial residues, often toxic, mutagenic, and carcinogenic, which interfere with our hormonal and reproductive systems. They are semi-volatile and circulate more or less readily in the air depending on temperature. They are lipophilic (low solubility in water but high solubility in fats), with a strong affinity for adipose tissue where they generally accumulate (high bioaccumulation). They also have a very long lifespan (persistence in the environment).

IV.3.4. Heavy Metals

Heavy metal is a broad term that describes a group of naturally occurring metallic elements of high molecular weight and density compared to water. At low concentrations, certain heavy metals, such as iron, zinc, copper, and manganese, are essential for human survival but can become toxic agents at higher concentrations. Other heavy metals, such as arsenic, cadmium, lead, thallium, and mercury, serve no biological role. However, they will inevitably enter the human body due to their presence in the environment. Similarly to essential metals, they induce toxicity once specific concentrations are reached.

Confirming the diagnosis of elemental toxicity is challenging as signs and symptoms are similar to those of many non-element-dependent diseases. Diagnosis of elemental toxicity requires demonstration of all of the following factors: (1) a source of elemental exposure must be evident, (2) the patient must demonstrate signs and report symptoms typical of the element, and (3) abnormal element concentration in the appropriate tissue must be evident. If one of these features is absent, one cannot make a conclusive diagnosis of elemental toxicity. The laboratory plays a vital role in this process, and appropriate specimen collection coupled with accurate analysis can aid in correct diagnosis.

Other specific sources of common heavy metals are listed below:

Arsenic (As): Inorganic arsenic, the toxic form of arsenic, is most commonly ingested from contaminated water and food. Sources of contamination include pesticides, smelting processes of copper and lead, wood preservatives, and volcanic eruptions.

Lead (Pb): Lead paint from older homes and lead leaching from pipes can still be a major source.

Cadmium (Cd): Inhalation is the primary route of cadmium exposure in the occupational setting. The amount absorbed from the lungs depends on the solubility and particle size of the Cd compound. Smoking is a significant source of cadmium

Mercury (Hg): The most common source of mercury is methylmercury, found in fish secondary to pollution. In adults, cases of methylmercury poisoning are characterized by the focal degeneration of neurons in brain regions such as the cerebral cortex and the cerebellum. Depending on the degree of in-utero exposure, methylmercury may result in effects ranging from fetal death to subtle neurodevelopmental delays. Consequently, because pregnant women, women of childbearing age, and young children are particularly at risk, the FDA recommends that they avoid eating shark, swordfish, mackerel, and tilefish

Thallium (TI): Sources include coal combustion, semiconductor manufacturing, and exhaust emissions. The clinical presentation of thallium toxicity varies based on dose, age, and acute or chronic exposure.

Chromium (Cr): The entry routes of chromium into the human body are inhalation, ingestion, and dermal absorption. Occupational exposure to Cr represents a significant health hazard. Cr is used extensively in the manufacture of stainless steel, in chrome plating, in the tanning of leather, as a dye for printing and textile manufacture, as a cleaning solution, and as an anticorrosive in cooling systems.

IV.3.5. Particles

The particles found in the air are called suspended particles this is the common name for all particles that float freely in the ambient air. The term aerosol refers to all types of suspended particles such as smoke, dust, and vesicles. Aerosols are classified, according to their formation mechanism, into primary and secondary particles. Primary particles are emitted directly in a particulate form, while secondary particles result from the atmospheric conversion of precursor gases into particles. Both types of particles are subject to growth and transformations, which allows the formation of secondary material on the surface of existing particles (adsorption).

Particles can also be subdivided according to their size; their diameter ranges from a few nanometers (nm) to tens of micrometers (μm). The size of particles significantly influences their physicochemical characteristics, mode of formation, impact on health and the environment, as well as their dynamics and lifetime in the air (transport and deposition).

The notation PM_X used in the study of particles refers to particulate matter comprising particles with a diameter of less than X μm . Based on the ability of particles to penetrate the respiratory system and the collection efficiency specific to aerosol samplers, the following classes are distinguished:

PM₁₀: Inhalable particles with an aerodynamic diameter of less than 10 μm .

PM_{2.5}: This category includes particles with a diameter smaller than 2.5 μm , commonly referred to as fine particles and/or respirable particles.

PM_{2.5–10}: Known as coarse particles, this fraction consists of particles with diameters ranging between 2.5 and 10 μm .

PM_{1–2.5} (intermodal class): These particles have diameters between 1 and 2.5 μm and mainly originate from the resuspension of soil dust.

PM₁: These are ultrafine particles with diameters smaller than 1 μm . They can penetrate deeply into the respiratory system and reach the alveoli.

Atmospheric aerosols play an important role in modifying living conditions on Earth. On one hand, they contribute to climate change by influencing the Earth's radiation budget. On the other hand, they can be harmful to human health. These two concepts are directly linked to the physicochemical characteristics of aerosols.

The depth of penetration and the deposition mechanism of solid particles in the respiratory system depend first on their aerodynamic diameters and the morphology of the airways, which determine the patterns of airflow.

According to certain estimates, the relative risks of mortality from cardiovascular diseases and lung cancer increase by 12% and 14% respectively for every $10 \mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$.

Among the effects associated with long-term exposure, we will mention: increased symptoms of lower respiratory tract conditions and chronic obstructive respiratory diseases, reduced lung function in children and adults, and shortened life expectancy due primarily to cardiopulmonary mortality and probably to lung cancer.

Table.1: Penetrability according to particle size (Zhang L, et al, 2019).

Particle size	Penetration degree in human respiratory system
$>11 \mu\text{m}$	Passage into nostrils and upper respiratory tract
$7-11 \mu\text{m}$	Passage into nasal cavity
$4.7-7 \mu\text{m}$	Passage into larynx
$3.3-4.7 \mu\text{m}$	Passage into trachea-bronchial area
$2.1-3.3 \mu\text{m}$	Secondary bronchial area passage
$1.1-2.1 \mu\text{m}$	Terminal bronchial area passage
$0.65-1.1 \mu\text{m}$	Bronchioles penetrability
$0.43-0.65 \mu\text{m}$	Alveolar penetrability

IV.3.6. Chlorofluorocarbons (CFCs)

Chlorofluorocarbons (CFCs), commonly known by the trade name Freons, are fluorinated gases derived from saturated hydrocarbons. They are composed of chlorine, fluorine, and carbon atoms. They are colorless, odorless, non-toxic, non-flammable, and non-carcinogenic. However, they contribute significantly to the greenhouse effect and to the depletion of the ozone layer.

CFCs have been widely used as refrigerants in refrigeration systems and air conditioners. They are also used as solvents in cleaning and stripping agents, as well as blowing agents in foam production. Their atmospheric lifetime ranges from approximately 20 years to several hundred years.

The five best-known CFCs are:

CFC-11 (trichlorofluoromethane, CFCl_3)

CFC-12 (dichlorodifluoromethane, CF_2Cl_2)

CFC-113 (trichlorotrifluoroethane, $\text{C}_2\text{F}_3\text{Cl}_3$)

CFC-114 (dichlorotetrafluoroethane, $\text{C}_2\text{F}_4\text{Cl}_2$)

CFC-115 (chloropentafluoroethane, $\text{C}_2\text{F}_5\text{Cl}$)

IV.4. The effects of different substances on the environment

IV.4.1. Effects on Human Health

Air pollutants can act at different levels of the human body: at the skin level, which is the case notably for irritating vapors and allergic reactions; at the level of mucous membranes; and at the level of the pulmonary alveoli. Pollutants dissolve and pass into the blood or superficial fluids; at the organ level, certain toxins carried by the blood can accumulate in organs.

The finer the particles, the deeper they penetrate into the respiratory system, and the longer they remain there. They have a dual action linked to the particles themselves and to the pollutants they carry (metals, hydrocarbons, sulfur dioxide, etc.). They irritate the human respiratory system and can contribute to the onset of acute respiratory diseases. SO_2 , for example, causes inflammation of the bronchial tubes with a spasm that leads to impairment of respiratory function; NO_2 is toxic (40 times more than CO, 4 times more than NO) and penetrates deeply into the lungs. Concentration peaks are more harmful than the same dose over a long period. NO is an irritating gas for the bronchial tubes and reduces the oxygen-carrying capacity of the blood. CO binds to hemoglobin in the blood. This process is irreversible. We are well aware of the fatal accidents linked to CO inhalation caused by the defective operation of water heaters.

IV.4.2. Effects on living organisms in general

Air pollution appears to have global consequences by affecting the health of many advanced living organisms, and even species considered primitive and resistant (lichens, algae, invertebrates, etc.). Pollution can directly kill organisms (for example, lichens are highly sensitive to acidic air pollution). It also has indirect impacts, for instance by degrading odors, hormones, or pheromones before they reach their targets. This phenomenon may partly explain the decline of certain bee populations and other pollinators (including some birds) observed in industrial and agricultural countries. It may also explain the reproductive difficulties of some species (lizards, snakes, amphibians, and certain mammals), where males and females fail to find each other effectively, as well as feeding difficulties in some species that can no longer properly detect odors guiding them to food sources.

IV.4.3. Effects on forest ecosystems and the phenomenon of acid rain

Plants are continuously exposed to atmospheric pollution. In some studies, they are used as bio-indicators (lichens, for example). They may suffer acute damage such as necrosis, as well as chronic damage such as growth disorders. Besides forests, air pollution also affects cereal crops and agricultural plants such as peas, spinach, and clover. Certain fruit tree species are particularly sensitive; apricot trees, for example, are highly vulnerable.

Plants are exposed both to pollutants suspended in the atmosphere, to dry deposition of dust and metals, and to acid deposits. They are affected directly through their foliage and indirectly through the soil (leaching of nutrients). Although each pollutant has a specific effect, acid deposition is especially harmful to plants. The protective layer of leaves and needles may suffer visible damage such as cracks and enlargement of stomata openings.

Rainwater flowing through forests has a lower pH than normal rainfall due to atmospheric pollution. Sulfur oxides (SO_2), produced by the chemical industry or by the combustion of petroleum and coal, and nitrogen oxides (NO_x), mainly from thermal power plants and vehicle fuel combustion, react with atmospheric moisture to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3), respectively.

Increased soil acidity can damage tree rootlets and affect the activity of microorganisms such as nitrogen-fixing bacteria. As trace elements, plants require metallic compounds such as copper, iron, and zinc; however, excessive accumulation of these metals leads to poisoning. The blockage of stomata by fine particles also contributes to tree decline. Therefore, air pollution is one of the many factors contributing to forest degradation.



Figure IV.1. Forest degradation caused by acid rain (source intrnet)

IV.4.4. Effects on materials

Materials are mainly affected by acidic pollution, which leads to the degradation of buildings, monuments, and building façades. Air pollution threatens cultural heritage and results in costly façade restoration and monument conservation works.

The degradation of materials (metals, stones, paints, fabrics, leather, plastics, rubber, paper, etc.) used in various applications (construction, large equipment, mechanical and electronic devices, coatings, etc.) occurs through abrasion, soiling, and corrosion. This process is driven by oxidizing and acidic substances carried by solid particles.

Paints may darken due to the deposition of black particulate matter. Freshly painted surfaces are usually sticky and tend to retain particles. In addition to material corrosion, another major impact of air pollution on built environments is surface soiling due to particle deposition. Fine particles, especially those emitted by diesel engines, can infiltrate indoor environments, causing soiling of walls, ceilings, carpets, etc. This degradation of the built environment is one of the most visible effects.

IV.4.5. Effects on freshwater ecosystems

Acidification of lakes and rivers leads to sometimes irreversible destruction of aquatic life. The decrease in pH causes the dissolution of metals naturally present in soil, such as aluminum, which is toxic in dissolved form to nearly all living organisms.

IV.4.6. Effects on climate and visibility

Atmospheric aerosols play a role in climate due to their influence on the radiative balance and on processes related to cloud formation and radiative properties. Aerosols scatter and/or absorb radiation (direct climate effects) depending on their chemical composition and size.

Visibility is the atmospheric quality that allows objects to be seen at varying distances and with varying clarity, including their color and texture details. Visibility is considered a component of well-being. Air pollution reduces visibility through light absorption and scattering.

Absorption is mainly caused by elemental carbon particles emitted particularly by diesel engines, and by gases such as nitrogen dioxide, which gives the atmosphere a brownish color. Scattering, caused by fine particles (PM_{2.5}), depends on particle size, atmospheric humidity, chemical composition, and formation processes.

Sulfates and nitrates, major components of PM_{2.5}, strongly scatter light and significantly reduce visibility. Humidity also plays an important role: the higher the humidity, the greater the light-scattering capacity of particles.

IV.4.7. Effects on climate and the greenhouse effect

Certain atmospheric pollutants, notably CFCs, destroy the ozone layer. Some human activities also release greenhouse gases into the atmosphere, causing a greenhouse effect that increases the Earth's average temperature. This anthropogenic influence began at the start of the 20th century (industrial era) and continues to increase.

The Sun continuously emits radiation (a mixture of visible light, infrared, and ultraviolet radiation) that travels through space. A portion of this solar radiation passing through the Earth's atmosphere is absorbed by the Earth's surface, which in turn emits infrared radiation (heat) back toward space. However, part of this infrared radiation is reflected back toward the Earth's surface by certain atmospheric gases called greenhouse gases. In simple terms, the atmosphere and greenhouse gases act like the glass of a greenhouse, trapping heat inside

Since the industrial era, concentrations of greenhouse gases have increased:

- ☐ CO₂ mainly from industrial, domestic combustion and transport.
- ☐ CH₄ mainly from agricultural practices such as rice cultivation and livestock farming.
- ☐ N₂O mainly from agricultural practices.

- CFCs (now banned), HFCs, PFCs, SF₆.

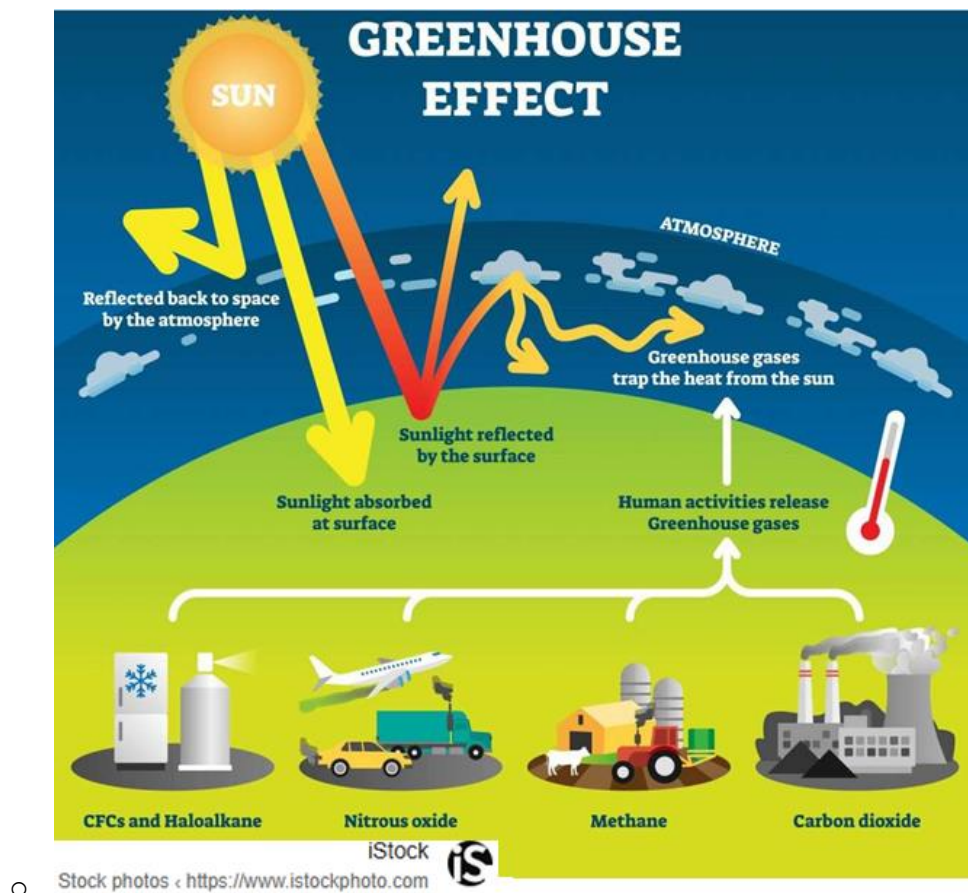


Figure IV.2. The principle of the greenhouse effect (source internet).

IV.4.8. Impact on aquatic ecosystems and eutrophication

Water pollution can be caused by several factors, including urban effluents from coastal areas, coastal industry, contaminated rivers, atmospheric deposition (industry, road traffic, etc.), as well as maritime navigation and offshore oil and gas extraction.

This pollution may be physical or chemical, including chemical pollution through eutrophication:

- Physical pollution: usually in the form of suspended matter (TSS), consisting of mineral substances (clays) and organic matter.
- Chemical pollution: dissolved chemicals altering water characteristics (acids, bases, etc.) or directly toxic substances (agricultural pesticides, etc.), as well as micropollutants.
- Chemical pollution via eutrophication: eutrophication corresponds to a disturbance of the biological balance of soils and waters due to polluted atmospheric deposition, such as excess atmospheric

nitrogen (NO_x and NH_3) beyond ecosystem absorption capacity, or excess nutrients (decomposable organic matter, nitrogen, phosphorus), or large discharges of fermentable organic matter into wastewater and agro-industrial effluents (dairies, slaughterhouses, canneries, etc.). Although not directly toxic, it causes serious disruptions of biological cycles when present in excess, leading to eutrophication.

IV.5. Ozone layer depletion

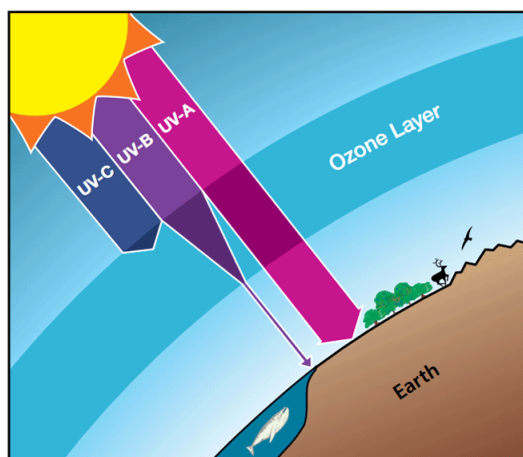


Figure IV.3.UV protection by the ozone layer (source internet).

Ozone is the main compound in the upper atmosphere at about 25 km altitude. Stratospheric ozone is considered “good ozone” because it absorbs solar UV radiation and protects us from skin cancer and genetic mutations. It also preserves plant photosynthesis.

An abnormal decrease in ozone concentration over the South Pole after the polar winter was observed in 1980. During late austral winter, when sunlight returns, ozone levels decrease by 40–60%, with maximum depletion occurring at 20–25 km altitude.

Many compounds can destroy ozone (OH , H , NO , Cl , Br , HO_2). A strong correlation has been observed between ozone depletion and ClO concentrations. The presence of Cl and ClO radicals in the stratosphere is linked both to natural emissions of methyl chloride from oceans and to chlorofluorocarbons (CFCs) emitted by human activities. CFCs are very stable molecules that reach the stratosphere, where they release chlorine and disrupt the natural ozone balance.

The annual ozone depletion phenomenon is more severe over the South Pole than the North Pole due to different conditions. In the South Pole, a vortex forms during winter with temperatures around -80°C to -100°C . Clouds containing ice crystals trap chlorine in the form of HCl and NO_2ClO . When

sunlight returns, UV radiation releases Cl and ClO radicals, which rapidly react with ozone. In the North Pole, no stable vortex forms, but multiple smaller depletion areas appear instead.

IV.6. Ozone peaks

Tropospheric, or ground level ozone, is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NO_x) and volatile organic compounds (VOC). This happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in the presence of sunlight.

Ozone and photochemical pollutants are also phytotoxic. Ozone can disrupt photosynthesis; reduce plant resistance, decrease productivity, and cause visible damage (tobacco variety Bel W3 is sometimes used as a bioindicator).

Ozone also contributes, along with acid deposition and other adverse factors (droughts, poor soils, etc.), to forest disorders observed in Europe and North America. Ozone pollution remains a concern, with seasonal summer episodes where harmful thresholds may be reached or exceeded.

IV.7. Types of emission sources

Potential pollutant sources may be natural or anthropogenic.

IV.7.1. Natural sources

Most aerosol emissions are attributed to natural sources such as suspended soil dust, oceans and seas, volcanoes, forest fires, and natural gas emissions.

Mineral soil particles represent a large part of natural primary PM. Their chemical composition and mineralogy vary regionally depending on geology. They generally consist of silicates (quartz SiO₂, clays, etc.), carbonates, and small amounts of calcium sulfate and iron oxides (Fe₂O₃). These particles may originate from local dust suspension in arid areas or long-range transport.

Volcanic emissions are also a source of primary mineral particles, but their contribution is limited in time and space.

Marine aerosols are mainly composed of sodium chloride (NaCl) and sulfates (Na₂SO₄, MgSO₄, K₂SO₄). They are produced by ocean waves and belong mainly to coarse particle modes.

Biogenic sources contribute to primary bioaerosols composed of plant debris, pollen, spores, and microorganisms (viruses, bacteria, fungi, algae). Viruses and bacteria are smaller than 2 μm , while others are coarse particles.

IV.7.2. Anthropogenic sources

Anthropogenic air pollution mainly results from gases and particles emitted by motor vehicles, heating systems, power plants, and industrial facilities (CO_2 , SO_2 , NO_x , dust, radioactive particles, and chemical products such as fertilizers and pesticides).

IV.7.2.1. Mobile sources

Vehicle emissions result from combustion, brake wear, tire wear, road surface wear, and dust resuspension. Road traffic is a major source of primary particles, depending on traffic density and atmospheric stability. Elements associated with vehicle emissions include Cu, Zn, Pb, Br, Fe, Ca, and Ba, mainly from non-exhaust sources such as brake and tire wear.

Marine engine emissions can also be significant sources of particulate matter and associated elements such as vanadium and nickel from fuel oil.

IV.7.2.2. Stationary sources

Major stationary combustion sources include power plants, waste incineration, and residential heating. Industrial processes such as steel production also require combustion. Particle properties depend on combustion conditions and fuel type (solid, liquid, or gas).

Industrial emissions include metallurgy, chemical production, material handling and extraction, and construction. Many emissions are fugitive, meaning they are not captured and are released from multiple points. Their properties depend on their formation processes.

IV.8. CORINAIR nomenclature

The CORINAIR nomenclature was developed by the European Environment Agency for compiling atmospheric pollutant inventories in Europe. It classifies emission sources into 11 categories and is also known as SNAP (Selected Nomenclature for Air Pollution). It contains nearly 400 items, grouped as follows:

1. Combustion in energy industries (electricity production, district heating, petroleum refining, coal transformation, mining, gas/oil extraction, compression stations)

2. Non-industrial combustion (commercial, institutional, residential, agriculture, forestry, aquaculture)
3. Combustion in manufacturing industries (boilers, turbines, engines, furnaces, energy processes)
4. Production processes (petroleum industry, steel industry, coal industry, non-ferrous metals, organic and inorganic chemistry, wood, food, paper, beverages)
5. Extraction and distribution of fossil fuels / geothermal energy (mines, fuel storage, extraction, unloading, distribution)
6. Solvent use and other products (paint application, dry cleaning, chemical manufacturing, anesthesia, cleaning products)
7. Road transport (cars, light vehicles, heavy trucks, motorcycles, fuel evaporation, tires, brakes)
8. Other mobile sources and machinery (military, rail, inland navigation, aviation, agricultural/industrial machinery, leisure equipment)
9. Waste treatment and disposal (incineration, landfills, cremation, wastewater treatment, spreading)
10. Agriculture and forestry (fertilized and unfertilized crops, burning, enteric fermentation, manure, pesticide use)
11. Other sources and sinks (forests, fires, wetlands, water bodies, animals, volcanoes, lightning, managed forests)

Chapter V: Environmental Protection



V.1.Introduction

Environmental protection consists of taking measures to limit or eliminate the negative impact of human activities on the environment. Environmental protection has several functions and involves different ecological principles of sustainable development. It prevents environmental damage (prevention principle), represses it (repression), and restores (biorestitution) as much as possible natural resources (biorehabilitation). Polluters should take responsibility for environmental management (polluter-pays principle) and should not be used to their advantage (cooperation principle). Environmental protection also includes ethical and aesthetic requirements. Environmental protection focuses both on different parts of the natural environment (such as soil, water, air, climate) and on the interactions between them.

V.2. Alternative solutions to the excessive use of natural resources

V.2.1. Introduction of new materials

The improvement of yields has always been a concern for industrialists, in order to combine the economic objective and minimize impacts on the environment by directing technological innovation in new directions. The choice of materials used requires significant product performance in terms of their energy consumption, and consequently new constraints in the design of their production, particularly with regard to their ease of recycling, in order to reduce the impact of the product at end of life and to reduce the quantities of solid waste generated by human activities.

V.2.2. Reserving Oil for Noble Uses

The energy transition toward sustainable development (post-oil) currently represents one of the greatest challenges of our time. This idea represents the only concept that can best ensure the energy and economic security of countries that rely almost entirely on oil, a resource that is being depleted. To this end, it is important to make better use of oil by reducing consumption through energy efficiency, and by reserving its use for noble purposes such as fertilizers, solvents, plastics, nylon, resin, and lubricants while replacing the use of oil with other renewable energy sources.

The underlying idea is that crude oil possesses immense chemical value and should not be viewed merely as a fuel. Combustion represents the simplest and arguably least sophisticated use of this resource.

This view is commonly attributed to Dmitri Mendeleev, who reportedly likened burning petroleum as fuel to feeding banknotes into a furnace. His point was that crude oil is a highly versatile feedstock composed of complex hydrocarbons that can be transformed into an enormous range of products.

V.2.3. Improving energy efficiency

Energy efficiency simply means using less energy to perform the same task – that is, eliminating energy waste. Energy efficiency brings a variety of benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering our costs on a household and economy-wide level. While renewable energy technologies also help accomplish these objectives, improving energy efficiency is the cheapest and often the most immediate way to reduce the use of fossil fuels. There are enormous opportunities for efficiency improvements in every sector of the economy, whether it is buildings, transportation, industry, or energy generation.

V.3. Waste Treatment and Recovery

The world faces a growing waste management crisis, driven by population growth, urbanization, rising incomes, and consumption, which is outpacing the capacity of local systems and municipal budgets. Yet this crisis also presents an opportunity: investing in efficient, inclusive and sustainable waste management can drive economic growth, job creation, and innovation, turning waste into a development asset rather than a burden. The World Bank's What a Waste 3.0 report captures this challenge in detail, offering the most current global data and analysis on solid waste management across 217 countries and economies and 262 cities, and providing a framework for understanding how policy choices can shape the future of waste management worldwide. At the root of this issue lies the fact that human activities generate solid, liquid, and gaseous waste that disrupts natural environments -water, atmosphere, and soil. In recent years, solid waste in particular has gained growing importance, not only as an environmental concern but also as a potential energy resource, with numerous projects in developed countries now focused on recovering energy from it.

V.4. Definition and Typology of Waste

According to European regulations, waste is defined as 'any substance or object which the holder discards or intends or is required to discard,' in other words, waste is defined as any material or object whose economic value is zero or negative for its holder.

The principles of waste management are primarily based on maximizing recovery and reuse, particularly of materials, in order to generate the minimum amount of rejects. Several methods are used, including source reduction to reduce toxic waste and other residues; another method of source reduction is to increase incentives for recycling. Several cities in the United States have implemented taxes whose amount is based on the quantities of garbage deposited (Pay As You Throw PAYT), which have proven effective in reducing the volume of urban waste. In some developing countries, waste recovery is carried out by hand-sorting to recover materials that can be resold on the salvage market.

The simplest classification of waste is characterized by their hazard level (explosive, toxic, flammable, capable of emitting harmful substances, etc.) and their impact on health and the environment. In contrast to hazardous waste, there is inert waste, which consists of mineral solids that undergo no significant physical, chemical, or biological transformation when landfilled and that are not contaminated by hazardous substances or other nuisance-generating elements likely to harm health and the environment. Inert waste therefore consists of construction and demolition residues originating from building and public works sites, as well as from mines and quarries.

Among others, there are other types of waste of diverse origin that have compositions whose evolution can generate multiple nuisances or environmental pollution; these include: waste assimilated to household waste, infectious waste, solid hospital waste, hazardous or special industrial waste (DIS), non-hazardous or ordinary industrial waste (DIB), ultimate waste, and anatomical waste.

V.5. Waste Management



Figure V.1.Waste management (source intrnet)

Waste management (Rudology) consists of collection, transportation, treatment, reuse, or disposal, all while being based on reducing the effects of waste on the environment. Waste management concerns all types of solid, liquid, or gaseous waste.

Some waste management experts have added a fourth R to the hierarchy of strategies, which is fundamentally based on the 3R rule (reduce, reuse and recycle). This fourth R (rethink) is based on prior optimization studies in order to produce as little waste as possible.

V.6. Waste Recovery

Waste recovery is the process of extracting value from waste materials rather than simply disposing of them. The fundamental principle is that almost all waste is potentially recoverable, provided the right method is applied based on the waste's specific properties:

Chemical nature: composition, reactivity, toxicity

Mechanical properties: density, particle size, strength

Physicochemical properties: solubility, viscosity, pH

Thermal properties: calorific value, combustion behavior

V.7. Waste Treatment Processes

V.7.1. Landfilling and Technical Landfill Centers

Landfills are engineered sites designed to safely store waste, and remain the most traditional and widely used method of waste disposal in most countries. While necessary for non-recyclable waste, traditional landfills are increasingly being replaced by controlled facilities known as technical landfill centers which incorporate modern technologies, such as methane gas capture systems, to minimize environmental impact.

Technical Landfill Centers (TLCs), often referred to as Centre d'Enfouissement Technique (CET), are highly engineered waste management facilities designed to dispose of solid waste safely while protecting the environment from contamination. They differ from open dumps by utilizing strict safety measures, such as impermeable liners and leachate collection.

V.7.2. Incineration

Incineration is the process of destroying a material by burning it. It is often called 'energy from waste.' In terms of energy comparison, it is estimated that the incineration of one tonne of household waste produces the energy that would have been provided by 150 liters of fuel oil. Energy production can be thermal in nature and thus serve, for example, to supply the heating needs of collective housing or nearby industries. The location of the facility must therefore be carefully chosen to balance the environmental aspect while preserving the economic interest linked to the necessary proximity to users. It allows for

savings on more valuable energy sources and helps reduce waste treatment costs for the community. The energy sold from the incineration of household waste, in the form of heat or electricity in France, was estimated in 2004 at nearly 13 million MegaWatt/hours (i.e., 1,350,000 tonnes of oil equivalent), a quantity equivalent to the total annual needs of a city of 400,000 inhabitants. Some facilities practice co-generation (combined production of electrical and thermal energy).

V.7.3. Thermolysis

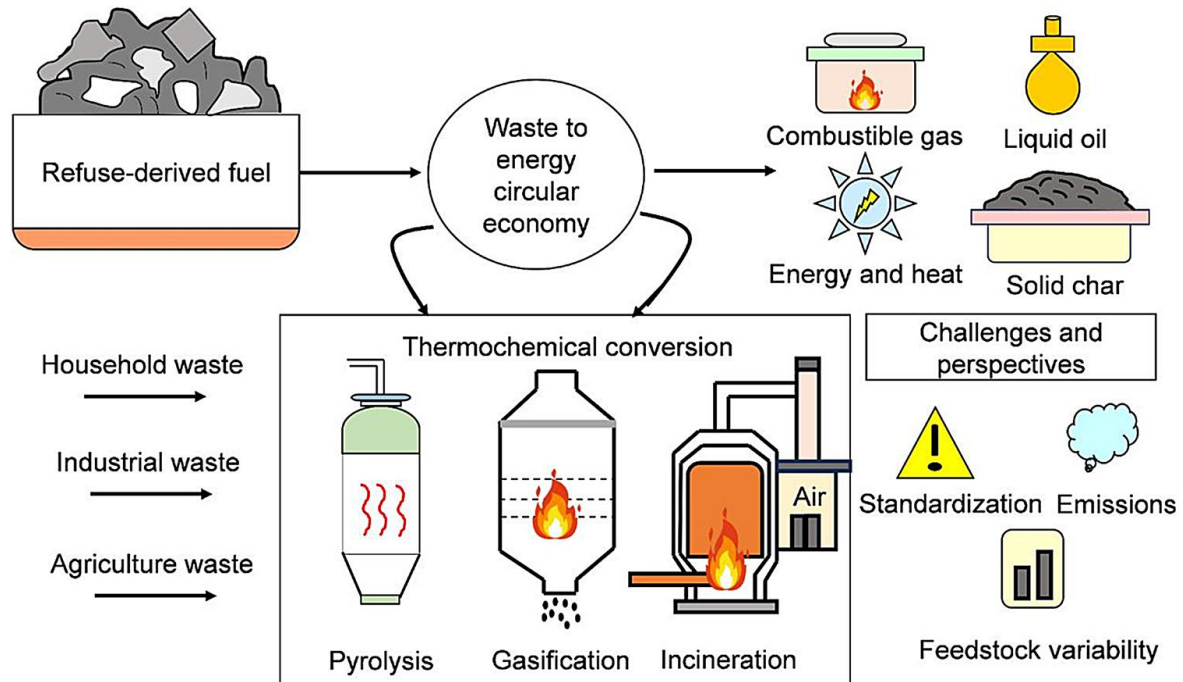


Figure V.2. Thermochemical conversion of waste into energy (source intrnet)

Thermolysis is a heat treatment process (450 to 2,000°C) carried out in the absence of air. It is applicable to organic materials, which it decomposes into three parts: a solid residue (composed of ash, minerals, and carbon), an oily liquid residue, and a hot gas.

V.7.4. Pyrolysis and Gasification

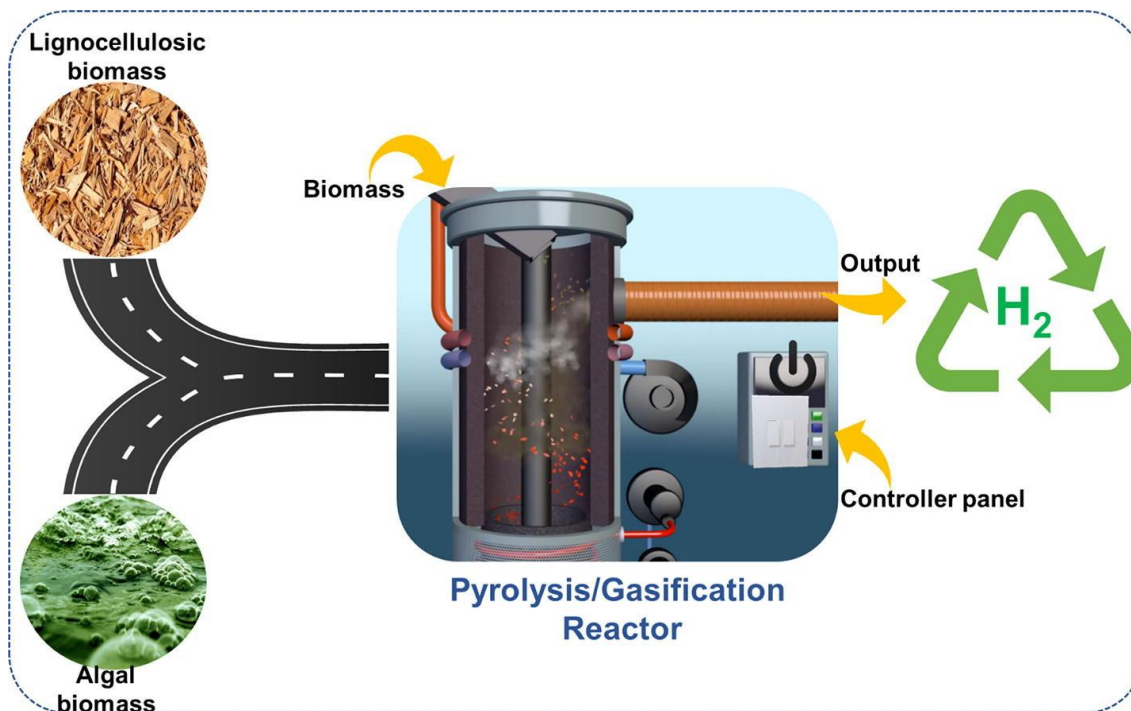


Figure V.3. Gasification and pyrolysis processes of lignocellulosic and algal biomass for hydrogen (source intrnet)

These are methods related to thermal treatments in which materials are heated to very high temperatures with little oxygen. This process is carried out in sealed tanks under high pressure. Both methods are more efficient than direct incineration in terms of the amount of energy recovered.

Pyrolysis transforms materials into solid, liquid, or gaseous products. Pyrolytic oil and gas can be disposed of by burning them to produce energy or refined into other products. Solid residues, on the other hand, can be transformed into other products such as activated charcoal.

Gasification (for example using plasma torches) is used to directly convert organic matter into a synthesis gas called syngas, composed of carbon monoxide and hydrogen. This gas is then burned to produce electricity and steam. This type of process is used in power plants for the production of renewable energy from biomass.

V.7.5. Composting and Fermentation

Organic waste, such as plant matter, food scraps, or paper, is increasingly being recycled. This waste is placed in a composter or digester to control the biological decomposition process of organic matter in order to eliminate pathogens. The resulting stable organic products are recycled as mulch or potting soil for agriculture or gardening.

At wastewater treatment plants, biological waste management favors returning fermentable fractions to the soil, either through the spreading of sewage sludge from treatment plants (a process that is increasingly contested and with an uncertain future), or after treatment by direct composting or by methanization followed by composting of the digestate.

As an example: the average household bin contains 29% fermentable matter, amounting to a total annual French figure of approximately 9.5 Mt; the agri-food industries produce 40 Mt; and French agriculture recycles approximately 30 Mt of urban and industrial organic waste and 280 Mt of agricultural effluents and residues each year.

V.7.6. Mechanical and Biological Treatment (MBT)

This process is a technique that combines mechanical sorting with biological treatment of the organic portion of municipal waste. The mechanical part consists of bulk sorting to remove all recyclable elements such as metallic materials, plastics, and glass, which will be processed so as to produce a fuel with a high calorific value. The biological part consists of anaerobic fermentation or composting.

V.7.7. Recycling

This treatment method mainly concerns glass, paper-cardboard, packaging and metals: these wastes are subject to a separate collection system that has long been well established, followed by specific value-added processing in the form of recycling: this involves the recovery of raw materials, without any true transformation.

In most cases, the material resulting from recycling is less expensive than the natural raw material and has the same properties. This simple observation allows us to conclude without much risk of error that recycling has a bright future wherever it is applicable.

Recycling can be:

- ☐ Mechanical: Waste reintroduced without chemical alteration.
- ☐ Energy/thermal: Waste burned to produce heat used as industrial energy.
- ☐ Chemical: Waste chemically transformed into new molecules, becoming intermediates for industrial processes.

V.7.8. Waste Recycling Center

This center ensures the collection and recovery of waste, which is then directed to the treatment process most appropriate to its nature, whether recycling, incineration, or disposal in a controlled technical storage facility.

V.8. Ecological Taxation

Ecological taxation, also known as environmental taxation or eco-taxation, is an emerging form of financial taxation in the service of environmental protection. It is considered an instrument for guiding the behavior of taxpayers with regard to the environment.

The use of taxation in environmental policies, in order to reduce pollution and environmental impacts linked to economic activities and consumption patterns, initiates a movement to integrate various market-based tools (tariff instruments, emissions permit markets, tax credits) and breaks with the common conception of the role of taxation. Ecological taxation represents, on average, 2.6% of the GDP of European Union countries; this rate is 2.3% in France; it peaks at 6% in Denmark.

Ecological taxation is today a major issue, at least in the debate, in the context of the fight against climate change: "carbon" or "carbon-energy" taxation is considered a fundamental instrument for reducing carbon emissions and controlling energy consumption.

The objective of ecological taxation is to correct market imperfections and not to collect resources in the most neutral way possible. Taxation therefore substitutes for standards in order to reduce pollution, by bringing the private cost of production to the level of the social cost (the latter includes damages caused to other agents the polluter-pays principle).

Assessing the social cost of damages, which corresponds among other things to evaluating the level of depollution as well as evaluating the responsiveness of behaviors to costs, is difficult. In any case, the tax is, in most cases, considered more efficient (more efficient because less costly than the emission standard). Indeed, unlike the emission standard, the tax (per unit of pollution) leaves a choice to the regulated company. The company faces two choices:

- Maintain its emission levels. It then avoids expenditure on improving its environmental performance but pays a high total tax. The sums collected in this way can finance environmental preservation expenditures.
- Choose to reduce polluting emissions. This entails expenditure on improving its environmental performance but reduces its tax burden.

The eco-tax is a means of incentivizing the polluter to depollute until the cost of depollution equals the amount of the tax. This implies more modern and therefore less costly production technologies in the company. The depollution policy through taxation is less costly than the implementation of a uniform quantitative standard. This is all the more true in a situation of imperfect information. The government decision-maker's depollution objective can be achieved in several stages, by modifying the level of the tax each time. If the emission level is too high, the tax level is increased. The process of achieving the set objective is carried out by trial and error. Eco-taxes make it possible to go beyond pre-existing standards.

Here are some examples of developed countries that have opted for eco-taxes:

- In Denmark: an energy tax was put in place after the oil shocks and now applies to all forms of energy. In 1991, a tax on carbon dioxide emissions was introduced to help combat the greenhouse effect, initially set at 13 euros per tonne of CO₂, but with partial exemptions for energy-intensive companies. In 1995, the CO₂ tax rose to 80 euros per tonne, but companies benefited in exchange from reductions in social charges. Eco-taxes brought in 320 million euros to the State in 2000, and 233 million euros of these revenues were allocated to charge reductions.
- In Norway: CO₂ taxes that came into force in 1991 made it possible to reduce emissions from fixed combustion installations by 21% per year. Studies have shown that a tax on CO₂ emissions, combined with reductions in labor contributions, would produce a moderate net gain in terms of employment.
- In France, the project to extend the General Tax on Polluting Activities (TGAP) to intermediate energy consumption, put forward in 1999, aimed to incentivize companies to reduce their polluting emissions. It quickly ran into the fact that any levy represented a burden.

V.9. Economic, Legal and Regulatory Mechanisms for Environmental Preservation

The depletion of natural resources and raw materials, as well as the problem of climate change, underline the necessity of the concept of sustainable development. Faced with this new phase of awareness of these environmental facts, public authorities intervene by using, without preconception, all available instruments to preserve the natural environment, accompanied by economic analysis that can assist political powers in their choices by proposing new instruments classified into two broad categories:

- Regulatory instruments (which set standards relating to technical processes or volumes of polluting emissions)
- So-called economic instruments (mainly eco-taxes and emissions permit markets, but also tax credits and subsidies).

V.10.The Role of Public Authorities in Resolving Environmental Problems

Public authorities must take into account the interests of individuals when making decisions that have an impact on environmental issues. In this context, it is important that the public is able to make observations to public authorities.

When public authorities must respond to complex environmental and economic policy questions, the decision-making process must include the carrying out of appropriate surveys and studies, so as to prevent and assess in advance the effects on the environment, and thus enable the establishment of a fair balance between the various interests at stake. The court has emphasized the importance of public access to the conclusions of these studies as well as to information enabling it to assess the danger to which it is exposed. However, this does not mean that every decision must be made solely in the presence of exhaustive and verifiable data on all aspects of the matter to be decided.

V.11. Current Environmental Policies

Based on economic instruments, current environmental policies rely less on regulatory instruments such as standards (which prescribe to agents the behaviors they must follow). Indeed, the use of standards presents, according to Boemare and Hourcade, "perverse" effects:

- Standards lead to additional costs explained by the difficulty of considering the diversity of solutions in order to require differentiated depollution efforts.
- Standards can in some cases fail to guarantee a reduction in total emissions.

V.12.The Tradable Emissions Permit Market

A tradable emissions permit (also called a "cap-and-trade" system) is a market-based regulatory approach to controlling pollution. Instead of the government simply telling every company "you cannot emit more than X amount," it creates a market where pollution rights can be bought and sold.

The traditional approach command-and-control regulation through the EPA's emission standards failed for a key reason: many regions simply did not meet the prescribed standards, yet the EPA lacked the flexibility to effectively respond. The result was a blunt measure: banning the installation of new factories in non-compliant regions.

This created an obvious economic problem economic growth was being blocked. The exemption through license transfer was the solution: new industrialists could still operate, but only by acquiring pollution licenses from existing ("historical") polluters who were willing to sell them.

Bottom Line

The tradable permits system is essentially a way of harnessing market forces to achieve environmental goals. It acknowledges that not all firms pollute equally or reduce emissions at the same cost, and uses that economic reality to reach environmental targets more efficiently than rigid, one-size-fits-all standards. The key insight is that it doesn't matter who reduces pollution, as long as the total reduction is achieved.

Semestre : 5
Unité d'enseignement : UET 3.1
Matière : Environnement et développement durable
VHS: 22h30 (cours: 1h30)
Crédits : 1
Coefficient : 1

Objectifs de l'enseignement:

Sensibiliser l'étudiant à la relation entre énergie, environnement et développement durable et maîtriser les sources de pollution ; les réduire afin de garantir un développement durable.

Connaissances préalables recommandées:

Mécanique des fluides, thermodynamique Fondamentale, transferts thermiques, et caractéristiques de l'environnement.

Contenu de la matière:

Chapitre 1. Introduction à la notion d'environnement (2 Semaines)

Définition de l'environnement, Définition générale, Définition juridique, Bref historique, L'homme et l'environnement, Comment l'homme a modifié son environnement, La démographie bouc émissaire.

Chapitre 2. La notion de développement durable (2 Semaines)

Définition, Bref historique, Les principes fondamentaux du développement durable, Le principe éthique, Le principe de précaution, Le principe de prévention, Les objectifs du développement durable, les enjeux environnementaux du développement durable.

Chapitre 3. Environnement et ressources naturelles (4 Semaines)

Introduction, Les ressources, L'eau, L'air, Les énergies fossiles (le pétrole, le gaz naturel, le charbon,...), Les autres énergies (solaire, Eolien, hydraulique, géothermie, biomasse,...), Les éléments minéraux, La biodiversité, Les sols, Les ressources alimentaires.

Chapitre 4. Les substances (4 Semaines)

Les différents types de polluants, Les polluants réglementés, Les composés organiques, Les métaux lourds, Les particules, Les chlorofluorocarbones, Les effets de différentes substances sur l'environnement, Effet de serre et changement climatique, Destruction de la couche d'ozone, Acidification, eutrophisation et photochimie, Les pluies acides. Les pics d'ozone ; Effets sur les matériaux ; Effets sur les écosystèmes : forêt, réserve d'eau douce, Effets sur la santé. Les différents types d'émetteurs, La nomenclature Corinair.

Chapitre 5. Préservation de l'environnement (3 Semaines)

Introduction de nouveaux matériaux, Réserve du pétrole aux usages nobles, Amélioration de l'efficacité énergétique, Le recyclage, Les mécanismes économiques, juridiques et réglementaires de préservation de l'environnement, Le rôle des pouvoirs publics dans la résolution des problèmes environnementaux, L'option envisageable des solutions privées, Les politiques environnementales actuelles, Le principe de pollueur-payeur, La fiscalité écologique: les écotaxes, Le marché des permis d'émission négociables.

Mode d'évaluation:

Examen: 100 %.

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- 3- Reed D. (Ed.), « Ajustement structurel, environnement et développement durable », l'Harmattan, Paris, 1995.
- 4- Vivien F.-D., « Histoire d'un mot, histoire d'une idée : le développement durable à l'épreuve du temps », Ed. scientifiques et médicales Elsevier ASA, pp. 19-60, 2001.
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Useful websites

<https://www.epa.gov/ground-level-ozone-pollution/ozone-national-ambient-air-quality-standards-naaqs>

<https://www.epa.gov/ozone-layer-protection/health-and-environmental-effects-ozone-layer-depletion>

<https://www.sciencedirect.com/science/article/abs/pii/S1364815204001458>

<https://www.resourcepanel.org/reports/global-resources-outlook>.

<https://www.recyclingtoday.org/pages/waste-management>

<https://www.epa.gov/landfills/basic-information-about-landfills>

<https://ejnet.org/landfills/>

<https://www.sciencedirect.com/science/article/pii/S0016236122029933>

<https://flexbooks.ck12.org/cbook/ck-12-cbse-biology-class-9/section/3.1/primary/lesson/food-resources/>