CHAPTER 1 : INTRODUCTION

I. FOOD INDUSTRY

I.1. Definition

- The food industry is the set of industrial activities that process raw materials from agriculture, livestock farming, or fishing into food products intended primarily for human consumption. The food sector can thus be defined in two sub-categories:
- **Agriculture**, which raises live animals, cultivates plants and fruits, and supplies them to the food industry.
- **The food processing industry**, which transforms raised live animals, cultivated plants, and fruits into finished food products ready for consumption. Highly heterogeneous, this sector covers several categories of activities, which are themselves subdivided into numerous fields. Three activities are classified as artisanal: pork butchery/charcuterie, bakery-pastry, and pastry. There are also much more concentrated and automated sectors such as sugar refining, brewing, oil milling, the dairy industry, flour milling, and beverages.

2. Waste and Discharges from the Food Industry

Organic waste and by-products from the food processing industries are generated by processing activities of plant and animal products. They exhibit high diversity and seasonal variability. They are characterized by significant heterogeneity and are mostly composed of organic waste. Some examples of generated waste include:

- **Meat industry:** fats, blood, bones, offal, leather, hair, feathers...
- **Fish industry:** fish bones, skins...
- **Dairy and cheese industry:** whey, wash water...
- **Sugar refinery, distillery:** molasses, pulp, pomace, filtration waste, effluents...

Article 3 of Law 01-19 of December 12, 2001, relating to waste management, control, and disposal, defines waste as follows:

"Any residue resulting from a process of production, processing, or utilization; any substance, material, product, or more generally, any movable property that the holder discards, intends to discard, or is required to discard or eliminate."

The food industry also generates packaging waste and mineral waste such as ash and lime treatment by-products. Examples include ash from the incineration of coffee grounds and sugar beet scum (defecation scum, where defecation is the treatment of sugar beet juice with lime).

This waste is intended to be discarded; however, a large portion of it can be recycled or valorized. Numerous recycling opportunities exist alongside the creation of new products from this waste, given that such products possess valuable physical characteristics and functional properties.

3- Classification of waste:

They are divided into three categories according to Article R. 541-8 of the Environmental Code:

– **Hazardous waste:** "Any waste displaying one or more of the hazardous properties listed in Annex I to this article. They are marked with an asterisk in the list of waste in Annex II to this article."

– **Non-hazardous waste:** "Any waste that displays none of the properties that make waste hazardous."

– **Inert waste:** "Any waste that does not undergo any significant physical, chemical, or biological transformation, does not decompose, burn, or produce any physical or chemical reaction, is not biodegradable, and does not damage other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health."

Then, depending on their origin and production sector, particularly in industry and healthcare facilities, these categories can be subdivided into different types:

4-Characteristics of industrial waste:

a- Inert industrial waste: construction rubble, excavated soil, etc. These are non-hazardous waste: mineral waste not subject to physicochemical or biological evolution.

Most inert waste, such as bricks, tiles, stones, and soil, originates from demolition or renovation sites. They are non-biodegradable and non-polluting residues. Indeed, they produce no chemical effect when interacting with other materials. This type of waste is often stored in waste disposal centers (recycling centers).

b- Non-hazardous industrial waste (ordinary industrial waste): plastics, paper, cardboard, etc. These are various materials not contaminated by pollutants or products that are hazardous to health and/or the environment; waste common to any business, such as plastics, paper, and cardboard; more specific waste (process waste, etc.); or non-hazardous, non-inert, and non-toxic waste.

c- Specific non-hazardous industrial waste: textiles, scrap metal, etc.

d- Hazardous industrial waste: These are wastes that, due to their hazardous characteristics (for health or the environment), require treatment in a specialized center.

Damaged batteries, pharmaceutical products, and paints are hazardous wastes that prove to be toxic to health. Furthermore, the outdoor accumulation of these wastes causes pollution of the water located near the storage site.

Organic: hydrocarbons, tars, solvents, paint sludges, etc.

• **Liquid or semi-liquid inorganic:** surface treatment baths, bases, etc.

• **Solid mineral:** quenching salts, foundry sand, etc.

• **DTQD (Hazardous waste in small quantities):** toxic waste produced in a scattered manner and limited in volume.

• **Healthcare activity waste (DAS):** waste resulting from diagnostic, monitoring, and preventive, curative, or palliative treatment activities in human and veterinary medicine.

DASRI (Infectious risk healthcare activity waste): sharps and cutting tools or materials, whether or not they have been in contact with a biological product.

Main characteristics of hazardous waste:

• Explosive and Oxidizing

• Extremely flammable, highly flammable

• Irritant, Corrosive, and Harmful

• Toxic and Carcinogenic

• Infectious and Toxic for reproduction

• Mutagenic

• Releases toxic or very toxic gas upon contact with water, air, or an acid; capable, after disposal, of yielding another substance that possesses any of the listed hazardous properties

5-Characteristics of Agro-Industrial Waste

Agro-industrial waste is primarily characterized by high biodegradability, high moisture content, and a rich organic matter composition.

1. Physical Characteristics

- **High moisture content:** Often exceeds 70–80%, making the waste fermentable and quickly putrescible (leading to odor generation and leachate production).
- **Variable particle size:** Depends on the sector (e.g., fine fruit pulp, olive pomace, whole carcasses, or skins).
- **Density and volume:** Massive, seasonal production concentrated over short periods (such as olive, wine, or fruit harvesting campaigns).

2. Chemical and Biological Characteristics

- **Organic richness:** High concentrations of carbohydrates, proteins, lipids, and sometimes lignocellulosic compounds (e.g., straw, hulls, cob residue).
- **C/N (Carbon/Nitrogen) ratio:** Variable depending on the byproduct; often high for woody waste or balanced for effluents and plant residues.
- **Presence of bioactive compounds:** Contains recoverable polyphenols, antioxidants, essential oils, or seeds.
- **Polluting potential:** Very high Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD_5) in liquid effluents, posing a severe risk of suffocating aquatic ecosystems if discharged directly.

II- IMPACT ON THE ENVIRONMENT

1. Impact on Water Resources (Aquatic Pollution)

Nowadays, we use more and more substances that contaminate water, including waste. Human discharge is the primary cause of freshwater pollution. At the same time, millions of tons of various types of waste are dumped into the oceans every year. This creates visual pollution as well as contamination of aquatic living species.

Most landfills are in the open air, which is inadequate and highly dangerous. When it rains, biodegradable waste mixes with water, and this reaction produces organic carbon that can cause acid rain. Consequently, this acid rain pollutes various water sources such as rivers, streams, and oceans.

There is a second source of water pollution: industrial waste discharged into lakes, rivers, and seas. Industrial waste can originate from various sources, such as cafeteria remnants, dirt, gravel, masonry, concrete, scrap metal, garbage, oil, solvents, chemicals, wood, and other hazardous industrial residues. Most of this waste is toxic; therefore, if poorly treated, it can cause numerous health and environmental problems.

Agro-food discharges (slaughterhouses, dairies, canneries, oil mills) are heavily laden with organic matter and nutrients.

- **Eutrophication:** Discharges rich in nitrogen (N) and phosphorus (P) lead to an excessive proliferation of algae on the surface. This blocks sunlight, and when these algae decompose, dissolved oxygen is completely consumed, creating "dead zones" devoid of aquatic life.
- **Asphyxiation of Aquatic Environments (BOD_5 and COD):** The degradation of organic matter by bacteria requires a large amount of oxygen. This results in a very high Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD), leading to the death of fish and aquatic fauna due to anoxia.
- **Contamination of Groundwater:** Infiltration of untreated wastewater or leaching from solid waste dumpsites contaminates groundwater with nitrates, metals, and pathogenic germs.

2. Impact on Soil

Soils contaminated by toxic compounds from waste can lose their ability to support plant life, thereby disrupting the entire food chain. Substances such as heavy metals and industrial chemicals can leach into the soil from poorly managed landfills, altering soil fertility and the health of local ecosystems.

Uncontrolled spreading or accumulation of liquid and solid waste modifies the physicochemical characteristics of soils:

- **Asphyxiation and Clogging of the Soil:** Fats, oils, and suspended solids form an impermeable film on the surface, preventing the penetration of air and water.

- **Acidification and Salinization:** Certain effluents (such as olive mill wastewater or dairy whey) are extremely acidic or high in salts, which destroys the soil structure and kills beneficial microfauna.

3. Impact on Air and Climate

The anaerobic decomposition (in the absence of oxygen) of accumulated organic matter produces:

- **Greenhouse Gas (GHG) Emissions:** Massive release of methane (CH_4) and carbon dioxide (CO_2), directly contributing to global warming.
- **Odor Nuisances and Toxic Gases:** Release of ammonia (NH_3) and hydrogen sulfide (H_2S), which are responsible for persistent foul odors and acid rain.

4. Effects of Waste on Biodiversity

Threats to Terrestrial and Aquatic Wildlife:

Solid waste can have devastating effects on terrestrial and aquatic wildlife. Land and marine animals often mistake waste for food, which can lead to the ingestion of toxic or non-digestible materials, causing internal injuries, poisoning, or death. For example, plastics and other debris can block the digestive tracts of animals, leading to starvation. Furthermore, seabirds, fish, and aquatic mammals can become trapped in nets or other waste debris, preventing them from moving freely or foraging for food, resulting in injury or death.

5. Impact of Waste on Society and the Economy

The impact of waste is not limited to the environment; it also has profound and multifaceted consequences for society and the economy. Poor waste management generates extremely high financial costs for communities and governments, which must allocate significant resources to cleaning up polluted sites, remediating contaminated soils, and treating affected water. These expenditures have an indirect effect on socioeconomic development, as they reduce the budgets available for essential sectors such as education, health, public infrastructure, and social programs. For example, in some major cities, millions of dollars are spent each year to collect litter abandoned on the streets or to manage illegal dumpsites, whereas these resources could be invested in building schools, modernizing hospitals, or supporting vulnerable populations.

III. Challenges of Treatment and Management of Agro-Industrial Waste

Introduction

Agro-industrial activities generate significant quantities of solid, semi-solid, and liquid wastes. Effective waste management does not simply mean disposing of these wastes. It involves reducing waste generation, ensuring proper collection and storage, selecting appropriate treatment methods, and recovering useful materials and energy whenever possible.

Therefore, the main challenges are related to **waste prevention, source reduction, sorting, collection, storage, treatment, recovery, and final disposal**.

III.1. Waste Reduction at Source

The first step in effective waste management is to **reduce the amount of waste generated directly during industrial processes**.

Waste reduction can be achieved through:

- optimization of production processes;
- reduction of raw material losses;
- improved storage of raw materials;
- regular maintenance of equipment;
- efficient use of water and energy;
- reuse of materials and by-products within the production process.

III.2. Waste Sorting, Collection and Storage

After generation, wastes must be properly **sorted, collected and stored**.

Sorting allows wastes to be separated according to:

- their nature;
- their origin;
- their hazardousness;
- their potential for recovery.

The main categories may include:

- organic waste;
- recyclable waste;
- inert waste;
- hazardous waste;
- non-recoverable waste.

Importance of waste sorting

Poor waste separation can:

- make treatment more difficult;
- reduce the recovery potential of materials;
- increase management costs;
- increase risks during handling.

Temporary storage must be carried out under appropriate conditions using suitable containers and designated storage areas.

III.3. Selection of Appropriate Treatment Methods

The choice of treatment depends mainly on the nature and characteristics of the waste.

Therefore, there is no single treatment method suitable for all agro-industrial wastes.

A. Biological Treatments

Biological treatments are particularly suitable for wastes containing high amounts of biodegradable organic matter.

The main processes include:

- Composting
- Anaerobic digestion (methanization)
- Biological treatment of wastewater

Composting

Composting is an **aerobic biological process** in which biodegradable organic matter is transformed into a stabilized product called **compost**.

Examples of suitable materials include:

- vegetable residues;
- fruit and vegetable waste;
- certain agricultural by-products.

Anaerobic Digestion

Anaerobic digestion is the biological degradation of organic matter **in the absence of oxygen**.

It mainly produces:

- **biogas**, which is rich in methane;
- **digestate**, which may be recovered and used under appropriate conditions.

Simplified process

Organic waste
↓
Anaerobic digestion
↓
Biogas + Digestate

III.4. Valorization of Agro-Industrial Waste

Waste valorization is one of the major challenges of modern agro-industrial management.

It involves considering certain wastes not simply as residues to be eliminated, but as **potential resources**.

Main forms of valorization

1. Material Valorization

This involves recovering or transforming valuable materials contained in waste.

Examples include:

- protein recovery;
- oil recovery;
- pectin extraction;
- recovery of antioxidant compounds;
- production of other value-added compounds.

2. Energy Valorization

Organic waste can be converted into energy.

For example:

Organic waste → Anaerobic digestion → Biogas → Energy

3. Agricultural Valorization

Organic waste can be transformed into products that may be used in agriculture.

Example:

Organic waste → Composting → Compost

Examples of waste valorization

Agro-industrial waste/by-product	Possible valorization
Fruit and vegetable waste	Composting, extraction of bioactive compounds
Whey	Recovery of proteins and lactose
Oil-rich residues	Oil recovery
Plant residues	Composting, anaerobic digestion
Organic waste	Biogas production
Protein-rich by-products	Animal feed, after appropriate treatment

III.5. Constraints in Agro-Industrial Waste Management

The management of agro-industrial waste faces several constraints.

1. Economic Constraints

Waste treatment may require:

- specialized equipment;
- qualified personnel;

- energy;
- treatment facilities;
- transportation;
- maintenance.

These requirements may represent a significant cost, particularly for small and medium-sized industries.

2. Variability of Waste

The composition and quantity of agro-industrial waste may vary according to:

- the type of industry;
- the raw materials used;
- the production process;
- seasonal variations;
- production volume.

This variability can make treatment selection and process optimization more difficult.

3. Technical Constraints

Some industries may lack:

- appropriate treatment equipment;
- adequate waste-management facilities;
- specialized personnel;
- appropriate monitoring systems.

4. Organizational Constraints

Effective management requires an organized system:

Generation → Sorting → Collection → Storage → Treatment → Recovery/Disposal

IV-What Are ISO Standards for Waste Management?

ISO standards, established by the International Organization for Standardization, provide international guidelines for various industries, including waste management. Among these standards, ISO 14001 and ISO 50001 are particularly relevant to our topic. They aim to improve companies' environmental performance by establishing environmental management systems (EMS).

1. Definition of ISO 14001

The NF EN ISO 14001:2004 standard defines environmental policy as a “statement by the organization of its intentions and principles in relation to its overall environmental performance, which provides a framework for action and for setting its environmental objectives and targets.”

ISO 14001 is a standard applicable to environmental management systems. It helps organizations address environmental concerns and meet the growing environmental expectations of consumers. It was developed by the International Organization for Standardization (ISO) and belongs to the family of organizational management standards.

1.2. Principles of ISO 14001

ISO 14001 applies to the environmental aspects that an organization can control and those over which it is expected to have an influence. It allows an organization to obtain certification from an accredited certification body.

The ISO 14001 standard is based on two main commitments: **continuous improvement and compliance with applicable legal and regulatory requirements.**

It provides a structured approach to implementing an environmental management system, ensuring traceability and strengthening the credibility of the organization's environmental practices through certification by an independent, accredited external body.

The standard is based on the principle of **continuous improvement of environmental performance** through the identification, monitoring, and control of environmental impacts associated with an organization's activities.

ISO 14001 is the internationally recognized reference standard for Environmental Management Systems (EMS). It helps industries identify, reduce, and control their environmental impacts, including those associated with waste generation, waste management, and waste traceability.

Methodological documents and guidelines are available to support the implementation of ISO 14001 procedures for industrial waste management.

I. ISO 50001 Standard

ISO 50001 is designed to help your organization improve its energy performance through better use of energy-consuming assets. Improving energy performance can quickly produce positive results by optimizing the use of available energy sources and resources, thereby reducing energy costs and consumption.

ISO 50001 is used by organizations of all types and sizes throughout the world. It offers several benefits. For some organizations, it helps reduce their environmental impact and improve their image. For others, its main objectives are to reduce costs and enhance competitiveness.

ISO 50001 defines a set of requirements that enable organizations to take action in several areas:

- Developing an energy policy to promote more efficient energy use.

- Setting targets and objectives to implement this policy.
- Collecting data to better understand energy use and make informed decisions accordingly.
- Evaluating the results achieved.
- Reviewing the effectiveness of the energy policy.
- Continuously improving energy management.

3-Eco-Management and Audit Scheme (EMAS)

In a nutshell, EMAS (eco-management and audit scheme) is a system for environmental management in the workplace. It incorporates tools for evaluating, reporting and improving environmental performance. The scheme, implemented by Regulation No 761/2001, includes the international environmental management standard ISO 14001, but is stricter. It requires a demonstration, through external verification of regular environmental statements, of the following: **legal compliance** (local, national and EU environmental rules and regulations), **continuous improvement** (i.e. actions taken to manage and reduce environmental impact), involvement of all staff, and public reporting, in the form of publication of the "environmental statement". Due to the legal compliance obligation, EMAS is site-specific and the certification bodies are in the Member States. It is important to note that EMAS is the strictest international environmental certification scheme available: the publication of regular statements verified by independent auditors ensures transparency and the scheme requires active communication both with staff and externally. Employees receive training in EMAS and their commitment and enthusiasm play an important role in the success of the scheme.

4-Directive (EU) 2018/851 on Waste

Directive (EU) 2018/851 of 30 May 2018 amends Directive 2008/98/EC on waste. It aims to improve waste management and promote the circular economy through waste prevention, reuse, recycling, and recovery.

Application to agro-industrial waste: This directive encourages food industries to reduce waste generation, sort waste at the source, and promote the reuse and recovery of waste whenever technically and economically feasible.

5-REACH Regulation (EC) No 1907/2006

The REACH Regulation, adopted on 18 December 2006 and in force since 2007, concerns the **Registration, Evaluation, Authorisation and Restriction of Chemicals**. Its main objective is to protect human health and the environment from the risks posed by chemical substances.

It places responsibility on companies to identify and manage the risks associated with the chemicals they manufacture, import or use.

Main components of REACH:

- Registration: collecting information about chemical substances.
- Evaluation: assessing the safety information and potential risks.
- Authorisation: controlling the use of certain substances of very high concern.
- Restriction: limiting or prohibiting certain hazardous substances when necessary

6-Regulation (EC) No 1069/2009: Animal By-Products

Regulation (EC) No 1069/2009 establishes health rules for animal by-products and derived products not intended for human consumption. Its main objective is to protect public health, animal health and the environment.

Animal by-products include slaughterhouse waste, animal blood, bones, feathers, manure and food products of animal origin that are not intended for human consumption.

7- Industrial Emissions Directive (IED) – Directive 2010/75/EU

Directive 2010/75/EU on Industrial Emissions aims to prevent and control pollution from industrial activities. It establishes rules to reduce emissions into air, water and soil, prevent waste generation, and protect human health and the environment.

The directive promotes the use of **Best Available Techniques (BAT)** to prevent or minimise industrial pollution and improve resource efficiency.

Application to agro-industrial activities: Food-processing industries should control their wastewater discharges, reduce air emissions, manage industrial waste properly and adopt appropriate pollution-prevention and treatment techniques.