CHAPTRE 2: Water Consumption in the Agro-Food Industry (AFI)

I. Water Sources and Water Requirements in the Food Industry

"Food processing water" refers to any water used during the manufacturing process, whether or not it comes into direct contact with the raw materials or the finished product. This includes water used to clean surfaces that come into contact with food.

I-1. Detailed Classification of Water Uses in the Food Industry

The analysis of water flows within a food-processing plant makes it possible to classify water requirements into four major functional categories.

.1. Water Incorporated into the Product (Ingredient Water)

This water is directly incorporated into the formulation of the final product and is listed among its ingredients. Its organoleptic, physicochemical, and microbiological characteristics directly influence the product's commercial quality and stability.

Examples of applications:

- Production of non-alcoholic beverages (NABs).
- Beer production.
- Reconstituted juice production.
- Preparation of curing brines.
- Cereal hydration in baking.
- Preparation of sauces and soups.

Critical requirements: Full compliance with drinking water standards, absence of undesirable flavor- or aroma-producing compounds (e.g., free chlorine), and strict control of mineral composition.

2-Contact Water and Raw Material Washing Water

This category includes water used for mechanical preparation and primary thermal conditioning operations, without intentional incorporation into the product.

Applications: Washing and trimming fruits and vegetables, hydraulic transport of delicate products (potatoes, tomatoes), evisceration in slaughterhouses, blanching, and scalding.

Associated Risk: Accumulation of organic matter and cross-contamination if the water is recycled without intermediate treatment.

.3. Industrial Water and Thermal Fluid (Service Water)

It serves as an energy-transfer medium in physical processing operations without direct contact with food.

- Steam production: Water is supplied to boilers for sterilization, cooking, and pasteurization. It requires highly demineralized water to prevent scale formation and boiler water carryover (priming).

- Cooling circuits: These include refrigeration units, cooling towers (CTs), and condensers. Strict control is required to prevent the proliferation of Legionella pneumophila.

.4. Cleaning and Disinfection Water (CIP Cycles)

Cleaning in Place (CIP) represents the largest share of water consumption in liquid food processing plants, such as dairy factories and breweries.

Stages of the CIP cycle:

- Pre-rinsing: Removal of coarse dirt and gross residues.
- Detergent washing: Cleaning using alkaline solutions (caustic soda) or acidic solutions.
- Intermediate rinsing: Removal of detergent residues.
- Disinfection: Elimination of microorganisms.
- Final rinsing: Rinsing with potable water.

Water consumption: CIP operations account for an average of 40% to 65% of the total water consumed at the industrial site.

I-2- Characteristics of Water Supply Sources

Food industries (Food Processing Industries – FPI) can obtain their water supply from three types of resources, each presenting specific advantages and technical constraints.

Water Source	**Technical Advantages**	**Disadvantages / Limitations**	**Required Pretreatment**
Public Water Supply (Drinking Water)	Guaranteed sanitary compliance and continuous availability.	High cost per m^3; chlorine may need to be removed when water is used as an ingredient.	Dechlorination using activated carbon and local softening.
Groundwater (Wells and Boreholes)	Relatively constant temperature, low microbiological and organic loads.	Often high hardness due to Ca^{2+} and Mg^{2+}; possible presence of Fe^{2+} and Mn^{2+}.	Iron removal (deferrization), manganese removal (demanganization), and water softening.
Surface Water (Rivers and Lakes)	Very large volumes available.	High seasonal variability, turbidity, micropollutants, and bacteria.	Clarification, coagulation–flocculation, and intensive disinfection.

II- In-Depth Analysis of Water Performance Indicators

A. Specific Water Consumption per Process (SECwater)

Specific Water Consumption (SECwater) is a fundamental benchmarking indicator. It relates the volume of water used within a production line or at a specific stage of the process to the quantity of compliant finished product manufactured.

Mathematical Formula for SECwater:

$$\text{SEC water} = \frac{\text{Vprocess}}{\text{Qproduct}}$$

Where:

- Vprocess: The total volume of water consumed within the unit (m^3 or litres).
- Q product: The mass or volume of finished product manufactured (tonnes, kg, or litres).

Impact on Food Quality and Safety

An abnormally high SECwater often indicates water leaks, excessive rinsing, or malfunctioning automated Clean-in-Place (CIP) systems.

Excess moisture accumulating and stagnating in production areas can promote the formation of bacterial biofilms, such as those associated with Listeria monocytogenes and Salmonella spp.

B-Water Recycling and Reuse Rate (Trec)

The Recycling Rate (Trec) quantifies the proportion of treated wastewater or recovered process water that is reintroduced into the industrial cycle instead of being discharged into the natural environment.

Formula for the Recycling Rate:

$$Trec\ \% = \frac{\text{V recycled}}{\text{V withdrawal} + \text{V recycled}} * 100$$

- Vrecycled: Volume of water reused in the industrial process.

- V withdrawal: Volume of fresh water extracted from sources such as boreholes or the public drinking water supply network.

C. Water Use Efficiency (WE)

Water Use Efficiency measures the efficiency of water resource utilization. It expresses the ratio between the useful volume of water (incorporated into the food product or strictly required for hygiene operations) and the total volume of water withdrawn.

Water Use Efficiency Formula:

Eh%=(V useful)/(V withdrawal)*100

In the agri-food industry, improving water use efficiency involves transitioning from manual open-jet cleaning systems to high-pressure, low-flow nozzles, as well as optimizing rinsing and sterilization cycles.

D. Water Use Intensity (Iwater)

Water Use Intensity is an economic and environmental indicator that links the physical consumption of water resources to the economic value generated by a production facility (Turnover or Value Added).

Water Use Intensity Formula:

Iwater= Vtotal consumed\ Value Added or Turnover

III-THE WATER FOOTPRINT

Definition and system boundaries

The water footprint is an indicator of water use associated with producing a good, providing a service, operating an organization or supporting a territory. Depending on the assessment method, it may account for rainwater consumed by crops, consumed surface water and groundwater, and the theoretical volume of water required to meet a water-quality target after a pollutant load is released.

Common units include L/kg, m^3/tonne, m^3/year, or m^3 per unit of product. The system boundary must be stated clearly, for example whether it includes agricultural production, transport and industrial processing.

Key point: the water footprint is not the same as the volume of water directly withdrawn by a factory. It may include upstream ingredients and a pollution-related component

2. The three components of the water footprint

2.1. Green water footprint

This is rainwater stored in the soil and used by plants, particularly through evapotranspiration.

Example: wheat grown without irrigation, relying on rainfall.

2.2. Blue water footprint

This is water consumed from surface-water and groundwater sources, such as rivers, reservoirs, lakes and aquifers. Examples include irrigation using reservoir water or water consumed by a factory from a well.

Water withdrawal is not always equal to water consumption because some withdrawn water may be returned to the environment.

3.3. Grey water footprint

This represents the theoretical volume of freshwater required to assimilate a pollutant load while meeting a specified water-quality standard. It is neither the actual volume of wastewater

discharged nor a recommendation to dilute wastewater. Preferred measures include reducing pollution at source and treating wastewater appropriately.