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Water Footprint Management in Agri-Food Industries

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Abstract:

Freshwater consumption in food processing industries is a significant factor affecting water resources and water environmental sustainability. Water footprint (WF), as a comprehensive assessment indicator, can be used to assess the consumptive water use in food processing industries. Industrial water management approaches can be divided into two parts: internal strategies and external strategies. At industrial level, water audit helps to find out actual water requirement at different processing stages. Similarly, if the water quality standards are adjusted to the particular process, water reuse can be more effective. Treated waste water can be use in different stages where it does not come in direct contact of food. Now a days, new technologies like use of infrared radiation, extracting water from crops, desalinization etc. also helpful to reduce water requirement. External strategies include both regulatory measures, such as gradually increasing water fees for increasing water volumes used, imposing specific water conservation taxes, incentives for green technologies etc. also require from government side. High innovation cost, low water pricing, lack of awareness are the main challenges, that why government support is require to improve water use efficiency.

Keywords: *Sustainability; water footprint; water reuse; green technologies; conservation taxes*

2.1 Introduction:

The need for food has increased due to the ever-increasing population growth, which has sped up change and led to an increase in the number of food manufacturers. In order to feed expanding populations (estimated to ~9 billion people by 2050), it was suggested during the 2009 World Summit on Food Security that global food production needed to increase by at least 70%. (FAO, 2009).

Water is necessary for food production, with agriculture alone using an estimated 70% of all freshwater extracted. Only 10% is used for domestic usage after an additional 20% is used in the production and processing sectors (UNFAO, 2012). (E.g. drinking water). According to studies, these pressures on freshwater will continue to rise as a result of a combination of socioeconomic demands, population growth, and climate change (SAB Miller and WWF, 2014).

Numerous indicators, including groundwater depletion, decreased river flow, and deteriorating water quality, show that present levels of water consumption in many regions of the world exceed sustainable levels (S.L. Postel, 2000). By 2030, it is predicted that worldwide water withdrawal would rise by 53%, from 4,500 billion m3/year to 6,900 billion m^3/year (McKinsey, 2009).

The globe is dealing with a difficult problem, as consumer demand for food is being driven by population increase, urbanization, and quickly rising economies (SAB Miller and WWF, 2014). More individuals are selecting western-style diets as a result of a growing middle class. These diets are heavy in fat, sugar, and protein, all of which require a lot of water to produce. Virtual water is the word used to describe the water used in the production of an agricultural or industrial product (D. Renault, 2002).

A person will ingest 2-4 L of water per day in addition to the 2,000–5,000 L of virtual water that is included in their daily meal. Water has a hidden cost in the food we consume. Water intake is significantly influenced by dietary choices. According to calculations of the water used in US meat production, raising beef takes 11 times more irrigated water than raising pork or poultry (G. Eshel., 2014).

There might be serious consequences, including increased food costs, food shortages, pollution, famine, social discontent, and geopolitical instability, if water consumption in the production of food and drink is not more effectively managed globally. In fact, it has been proposed that this may trigger a "global water war" (S. Goldenburg, 2014).

To determine if water usage is sustainable, it is necessary to examine water consumption in primary production systems and comprehend how it affects water availability. In order to lessen its consumption of water resources and decrease risk associated with water, the agrifood business has been compelled to adopt a responsible approach to developing water plans (T. Lambooy, 2011).

2.2 Water use in agri-food system:

The largest consumer of freshwater on earth is the agriculture industry. Similarly, one of the major uses of water is industry. With an increase in income, industrial water usage rises.

In low-income nations, industrial usage only makes for 2% of all freshwater withdrawals, but in high-income countries, industrial use may account for up to 43% of all water consumption. In certain high-income nations like Canada, France, Germany, the United Kingdom, and Switzerland, it may make up as much as 69–75% of all water usage (World Bank,2011) (Figure 2.1).

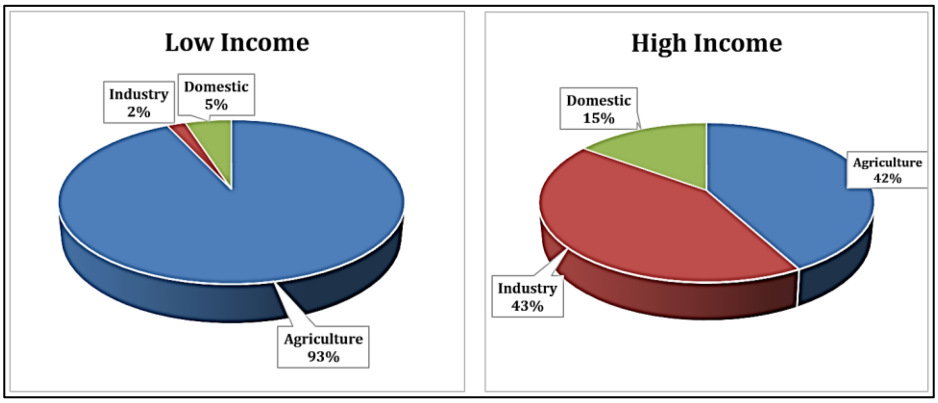

Figure. 2.1: The dependence of sectoral breakdown of annual freshwater withdrawals to income levels (Data obtained from World Bank, 2011)

The food processing sector, which comes in third after the chemical and refinery sectors, uses a lot of water. In certain specialized areas of the food business, sanitation procedures account for about 70% of all water usage (Henningsson et al., 2004). As a result, washing and sanitation procedures are a top priority in lowering the food industry's overall water use. Cooling and heating come in second, using 20% or more of the total water used in the food sector. Even in the brewing and soft drink industries, only 20 to 30% of the water used makes it into the final food product. Thus, in average, more than 70% of the total water utilized is released as effluent, which has significant quantities of fats, oils, and grease as well as biological oxygen demand (BOD) and chemical oxygen demand (COD) (FOG). The food and beverage business, out of all the other industries, contributes the most to the emissions of organic water pollutants. The food and beverage sector accounts for between 10 and 30 percent of all industrial emissions of organic water pollutants in high-income nations (World Bank, 2011) (Figure 2.2).

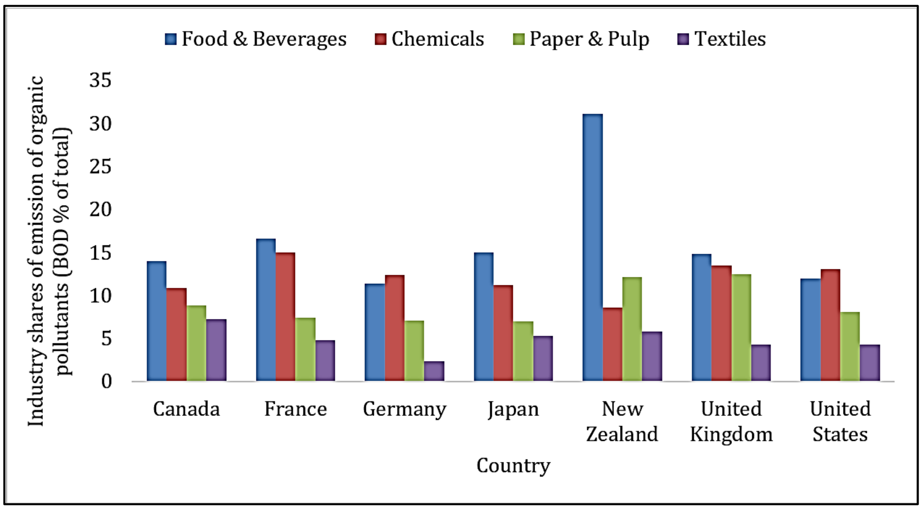

Figure 2.2: Industry shares of emission of organic pollutants (BOD % of total) (World Bank, 2011)

Wastewater from the food processing sector might have BOD and COD levels that are 10–100 times greater than home wastewater (FDM-BREF, 2006). The effluents from food processing factories have a significant influence on nearby water bodies because of the large organic load and high COD and BOD demand. The adoption of water conservation measures in the food business is significantly hampered by the laws governing food safety. The existing laws allow processors to recycle or reuse water as long as it doesn't endanger the finished product's safety or wholesomeness (Council Directive 98/83/EC). The meat, dairy, and vegetable processing industries are among the activities included in the European Commission (EC) Council Directive 96/61/EC on Integrated Pollution Prevention and Control (IPPC) that is laying out steps to decrease emissions in water. The organo-halogen chemicals, which are mostly linked to the use of chemical sanitizers, are included in the indicative list of the major pollutants. The need to develop eco-efficient innovative technologies that will help reduce water consumption and wastewater generation rates while also improving wastewater quality in the food industry is therefore necessary. Sustainable water use is one of the environmental challenges facing the food industry.

2.3 Water Consumption Reduction Strategies in the Food Processing Factories:

Food manufacturers have been lawfully adding water to their goods ever since the first foods were processed. In addition, water may be utilized for cleaning, transportation, and heat transfer. The effective use of water and the regulation of wastewater quality are the two key areas of attention for water management in the food sector. Since highly contaminated wastewater discharges, rather than water usage, are what have the greatest industrial impact on water resources, wastewater management and quality are of utmost importance.

Food firms may monitor their water usage and the effects of their goods on water resources by using the water footprint (WF), a tool that has been designed specifically for this purpose. The private sector may analyse risks and find hotspots in the supply chain using the information supplied by the WF. Food companies are now working very hard to reduce the amount of water used during processing since they stand to benefit greatly. Industrial water management approaches come in two flavours: internal strategies and external strategies (Grobicki, 2008).

2.3.1 Internal Strategies:

A. Water auditing:

A fraction of total water consumption is accounted for by leakage, some of which is the result of inaccurate metering, some of which is unauthoritative use, and some of which is water provided to consumers. A water audit identifies the locations and quantities of water usage. Depending on the data available on the system, the water audit's level of detail will change (Ganorkar et al., 2013).

One of the objectives of the water audit is to reduce physical losses caused by pipe leaks and overflows, losses from metering mistakes, unauthorised connections, and free water supplies given by the municipal authority for public stand posts and parks in the distribution system (Ganorkar et al., 2013).

B. Water reuse:

If the water quality standards are adjusted to the particular process, water reuse can be more effective. Examining key control points and determining the risk of food contamination are necessary in order to match the water quality criteria to the kind of water consumption. The water used for rinsing, for instance, may be transferred to the washing tanks and then used once more for the pre-washing procedure. As an alternative, receiving areas for raw materials might be cleansed using rinse water. These ideas put into practice might result in a 30% reduction in water use (Gil et al., 2009). As a result, when it is feasible, industrial water reuse should be integrated into existing HACCP systems in addition to creating a framework for water reuse in food production and processing (Figure 2.3).

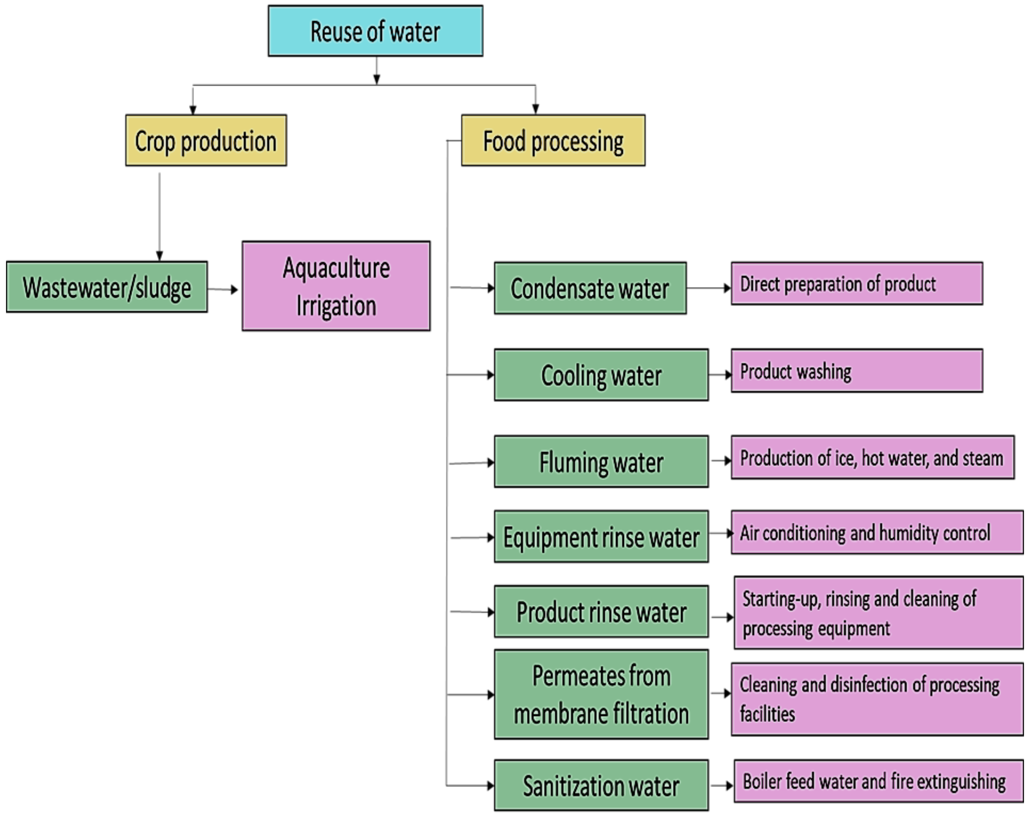

Figure 2.3: Water reuse in food and beverage production (Source: CODEX Alimentarius Commission, 2001)

C. Water recycle and reclamation:

Water reuse is described as the use of water in several processes where increasingly lower quality water is required, whereas recycling is the act of bringing treated water back into service after having been used before for a variety of purposes. Reusing wastewater produced elsewhere once it has been adequately cleaned is known as water reclamation, and it is one more way to increase industrial water efficiency.

If recycled water will come into contact with food or drink products or is used to clean surfaces that will come into contact with them, it will need to be treated to improve its quality (Table 2.1)

Table 2.1: Overview of representative unit processes and operations used in water reclamation (Ölmez, 2013).

Process	Description	Application
	1. Solid/liquid separation	
Sedimentation	Gravity sedimentation of particulate matter, chemical floc, and precipitates from suspension by gravity settling	Removal of particles from turbid water that are larger than 30 mm
Filtration	Particle removal by passing water through sand or other porous medium	Removal of particles from water that are larger than about 3mm. Frequently used after sedimentation or coagulation / flocculation
	2. Biological treatment (wastewater)	
Aerobic biological treatment	Biological metabolism of wastewater by microorganisms in an aeration basin or biofilm process	Biological metabolism of wastewater by microorganisms in an aeration basin or biofilm process
Biological nutrient removal	Combination of aerobic, anoxic, and anaerobic processes to optimize conversion of organic and ammonia nitrogen to molecular nitrogen (N_2) and removal of phosphorus	Reduction of nutrient content of reclaimed water
Waste stabilization ponds	Pond system consisting of anaerobic, facultative and maturation ponds linked in series to increase retention time	Reduction of suspended solids, BOD, pathogens, and ammonia from wastewater
Disinfection	The inactivation of pathogenic organisms using oxidizing chemicals, ultraviolet light, caustic chemicals, heat, or physical separation processes (e.g. membranes)	Protection of public health by removal of pathogenic organisms
	3. Advanced treatment	
Activated carbon	Process by which contaminants are physically adsorbed onto the surface of activated carbon	Removal of hydrophobic organic compounds
Air stripping	Transfer of ammonia and other volatile components from water to air	Removal of ammonia and some volatile organics from water

Process	Description	Application
Ion exchange	Exchange of ions between an exchange resin and water using a flow through reactor	Effective for removal of cations such as calcium, magnesium, iron, ammonium, and anions such as nitrate
Chemical coagulation and precipitation	Use of aluminium or iron salts, polyelectrolytes, and/or ozone to promote destabilization of colloidal particles from reclaimed water and precipitation of phosphorus	Removal of particles by sedimentation and filtration
Lime treatment	The use of lime to precipitate cations and metals from solution	Used to reduce scale-forming potential of water, precipitate phosphorus, and modify pH
Membrane filtration	Microfiltration, Nano filtration, ultrafiltration	Removal of particles and microorganisms from water
Reverse osmosis	Membrane system to separate ions and particles from solution based on reversing osmotic pressure differentials	Removal of dissolved salts and minerals from solution; also effective for pathogen removal

D. Implementation of best practices:

With little financial effort, simple operational and cultural changes may often cut water use by up to 30%. As a first step in reducing wastewater output at the processing plant, it is advised to do the washing, grading, and trimming of raw products in the field. Other useful strategies used by the sector include using air cooling rather than hydro cooling, switching from water to steam blanching, using multi-stage countercurrent washing systems, installing high-pressure cleanup systems for plant sanitation operations, reusing water in another processing step, and separating low and high-strength waste streams, among others.

Investment in Water-Efficient Technologies:

A. Extracting Water from Food:

One of the food production processes that use the least amount of water is the processing of sugar beets in Europe. A sugar beet typically contains 75% water, and this water is utilized to produce sugar. In the UK, the water utilized in manufacturing operations originates from the sugar beet itself in excess of 60% of the time (Sugar et al; 2011). After being cleaned on-site, the water used to make sugar from sugar beet is either released into nearby water sources or reused for agriculture. Grey water anaerobic digestion also yields biogas, which is subsequently usable as a thermal process fuel (CIBE and CEFS environmental report, 2003). This is a nice illustration of an integrated process created and applied using chemical engineering concepts. PepsiCo does the same thing by drawing water out of potatoes. Process water efficiency has increased by PepsiCo by more than 20% (Pepsico Water report, 2014). To extract water from potatoes before they are cooked to make crisps, chemical engineers have invented a technique. The business is able to capture water and reuse it throughout their plants thanks to thermodynamic technology (stack heat).

B. Rainwater Capture:

Green water, or rainwater, is frequently used in agriculture. Utilizing rainwater effectively is become more typical in the food production process.

C. Desalination:

Large-scale desalination of water requires a lot of energy and is not economically feasible for most nations. In dry areas (such as the Middle East), excessive groundwater use has led to a dependency on salt water desalination as a source of potable water for human use. Thermal energy (using phase-change processes) or electrical energy (powering membrane processes) are the two energy sources that enable water desalination, and both technologies are most suited to the individual needs (Al-Karaghouli et al., 2009).The feasibility of using desalinated water in the food business may be improved by new advancements that employ renewable solar and wind energy to power the desalination process. It is possible to treat water with solar thermal desalination by using a variety of chemical engineering techniques (eg distillation, separation and solar still methods). These technologies are still in the early stages of development and are pricey. However, there is a lot of promise.

D. New Innovative Technologies:

Now days, food processing industries give focus on development of innovative green technologies to reduce water requirement. For example, peeling of tomato with infrared dry peeling technology (Xuan Li et al., 2014), use of pulse light in salad industry (Manzocco et al., 2015), water reclamation from the sorting/grading operation in mandarin orange canning production (Wu et al., 2016), water footprint study in gazpacho soup (Ibáñez et al., 2017), reducing water footprint by changing diet and imported products (Mirzaie et al., 2020) etc. Government also provides incentives for green technologies which motivate researchers and food scientists to discover new technologies.

2.3.2 External Strategies:

External strategies include both regulatory measures, such as gradually increasing water fees for increasing water volumes used, imposing specific water conservation taxes on operations using more than a certain amount of water, and requiring pre-approval from local authorities for new factories anticipating more than a certain level of water consumption on a monthly or annual basis. Making decisions regarding purchasing water recycling and wastewater treatment systems involves weighing several costs, including those related to water supply and effluent discharge. Therefore, strict environmental laws will be crucial in promoting the creation and application of eco-innovative technology for responsible water use.

A major objective of the sector for sustainable water use is zero water discharge, which means that all wastewater effluents that would typically be released into the environment are treated, recycled, or sold to other users (Gorbicki, 2008; Bagajewicz, 2000). The idea is to reduce the amount of fresh water used in single- or multiple-contaminant systems in the industry (Koppol et al., 2003).

2.4 Challenges and opportunities:

The creation or adoption of eco-innovative procedures that would lessen the negative effects of the food industry on the environment and on natural resources, especially on water, is one of the major difficulties facing the food industry in ensuring its sustainability. When possible, water-based technologies should be replaced with "water-free technologies," and a well-proven systematic strategy to reducing water consumption during processing should be used to minimise water use and wastewater discharge in the food business.Nevertheless, there are a number of obstacles to boosting water efficiency in the food processing sector.

The first is the expense in terms of the amount of time and money required to put a water management strategy into action. The second is the low water pricing, which make investing in water management systems unreasonable from a cost-profit perspective (Wallis et al., 2007).

The food business has a vital potential to improve the efficiency of its water consumption through technological advancements. Due to technical advancements in the water-intensive sectors, it is anticipated that by 2030, the industry's water usage would have decreased by 25–36%, depending on the industry (Florke and Alcamo, 2004).

Government backing of technical advancements aimed at increasing water efficiency in business is crucial. This should encompass both support for the industry's adoption and investment in water-efficient technology, as well as funding for all relevant areas of research. The industrial grant programs may serve as incentives to get business to spend money on water-saving equipment.

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