Advancing Water Reuse Within the Beverage Industry

Disclaimer

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A Call to Action: Notes from the Action Leaders and Partners

Water is essential to the beverage industry as it is used in every facet of it. Water is used to irrigate and cultivate ingredients and is an ingredient in beverages. Water is a key process component in beverage manufacturing and is used to dispense and serve beverages to consumers. Without sufficient water, beverage companies cannot produce their products.

Water supply, quality, demand, and wastewater generation are meaningful in this sector. Water is a limited natural resource facing unprecedented local and global challenges. Water supply and disposal options are often constrained due to regulations governing discharge quality and environmental factors such as droughts. Across industry, and especially in regions where water scarcity is pronounced, these issues drive higher costs for beverage manufacturers to produce their products, not only to access source water, but also to dispose of wastewater. These complex water challenges have motivated corporate personnel, regulators, consulting engineers, equipment and technology providers (referred to herein as "water professionals"), and consumers to seek and develop solutions to help the beverage industry optimize water usage and operate sustainably.

Toward this end, water reuse offers a compelling opportunity for beverage manufacturers. By recycling water for non-ingredient (or non-product) purposes onsite, beverage manufacturers can minimize their demand for water from off-site sources, as well as the volume of wastewater taken off-site for disposal. Beverage manufacturers can also optimize water recovery and reuse onsite, elevating operational efficiencies, reducing costs, and achieving sustainability goals.

The United States Environmental Protection Agency (USEPA) coordinates the **National Water Reuse Action Plan (WRAP)** that promotes collaboration among the water sector to address barriers and drive opportunities for water reuse in the public and private sectors. As part of **WRAP Action 5.7,** a diverse group of action leaders and partners convened to assess barriers and opportunities for water reuse in the beverage industry. Based on feedback from the Action Partners and the public, the Action Leaders formed three subcommittees to investigate barriers to water reuse in the beverage industry based on three key topics: Stakeholder Engagement, Regulatory Environment, and Treatment and Technology. This paper is generally organized by these topics and is the primary output of WRAP Action 5.7.

The purpose of this paper is twofold:

- Increase understanding of the stakeholder engagement, regulatory, and treatment and technology issues related to water reuse within the beverage industry.
- Identify key hurdles and near, medium, and long-term solutions to advance water reuse practices at beverage manufacturing plants. If the near-term solutions are implemented, then beverage manufacturers may be able to advance water recycling strategies at their facilities in due course.

The findings presented in this paper represent a novel, collaborative effort among federal and local regulators, major international beverage manufacturers, non-profit organizations, consulting engineers, and water professionals.

The action leaders and partners intend to convene in 2024 to review the recommendations herein, share results with the broader community, and determine next steps (including detailed tactics and ownership of tasks) to help advance water reuse in the beverage industry.

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Acronyms and Abbreviations

BIER	Beverage Industry Environmental Roundtable
CGMP	Current Good Management Practice
FAO	Food and Agricultural Organization
HACCP	Hazard Analysis Critical Control Point
JEMRA	Joint Expert Meeting on Microbiological Risk Assessment
NGO	Non-Governmental Organization
NPDES	National Pollutant Discharge Elimination System
NYWEA	New York Water Environment Association
PC	Preventive Controls
SFPUC	San Francisco Public Utilities Commission
USEPA	United States Environmental Protection Agency
USFDA	United States Food and Drug Administration
WEF	Water Environment Federation
WHO	World Health Organization
WRAP	Water Reuse Action Plan

01 - The Water Reuse Journey in the Beverage Industry

The WateReuse Association (WateReuse) **defines water reuse** as “the process of intentionally capturing wastewater, stormwater, saltwater, or graywater and cleaning it as needed for a designated beneficial freshwater purpose such as drinking, industrial processes, surface or ground water replenishment, and watershed restoration” (WateReuse Association, 2023). USEPA’s **Regulations and End-Use Specifications Explorer** (REUSExplorer) tool further differentiates industrial reuse as “the use of recycled water for industrial applications (including beverage manufacturing), often created at the industrial facility. This includes recycled water generated through onsite processes such as boiler water, cooling water, manufacturing water, and oil and gas production, as well as recycled water generated off-site and imported elsewhere for industrial reuse applications” (USEPA, 2023). Furthermore, the **Codex Alimentarius Commission** defines water reuse in food and beverage manufacturing as “water that has been recovered from a processing step within the food or beverage operation, including from the food components and/or water that, after reconditioning treatment(s) as necessary, is intended to be (re-)used in any processing operation (FAO and WHO, 2019).

This white paper is focused on onsite water reuse, where process wastewater generated within a beverage manufacturing plant (“inside the fence”) is captured, treated, and reused in manufacturing processes. Examples of onsite water reuse applications at these facilities include the treatment of process wastewater for washing of pipes, equipment, and floors. Note that process wastewaters are byproducts of highly controlled production processes using ingredients and chemicals in predefined amounts and concentrations. Less variability in flow, volume, or composition is expected, and water reuse is considered potentially more feasible as a result. Sanitary wastewater generated by employees on site (blackwater) and storm water capture and reuse are not addressed in this paper. Any interface with municipal water supply or wastewater treatment facilities for source water or disposal is also not addressed in this paper.

Beverage manufacturing comprises a broad range of consumer products, including soft drinks and juices, and fermented or distilled products such as beer, wine, and spirits. Beverage manufacturing facilities producing these goods are the focus of this white paper. Other types of food manufacturers and their products, such as milk or other dairy goods, are excluded from our discussion. We generally assume treated water generated by a water reuse system is not used as an ingredient in consumer products in the near term, but that it could be used in this manner in the future.

There are many drivers and benefits associated with implementing water reuse practices at beverage manufacturing plants. One driver is a business case for water stewardship. Beverage production requires water. Many beverages contain water as an ingredient. Water for cleaning and sanitation ensures products are safe. Yet water stress continues to increase in many communities where beverage operations exist. Manufacturing in these locations requires businesses to understand the impact they have on the community. Water stewardship strategies addressing limited resources for locations with high water availability risk can benefit communities and businesses. Though the focus of this paper is water reuse within manufacturing operations, strategies can extend beyond the manufacturing walls to include investing in projects that help replenish watersheds and sustain healthy community water supplies.

Another driver is a company’s reputation. The perception of unfair or irresponsible water use has potential to materially affect consumer behaviors. The role of social media in activism can lead to viral publicity, negative or positive; understanding consumer preferences and positions is a competitive advantage. A **benchmark comparison for valuing water in the beverage industry** highlights the opportunity for beverage companies to do more (Ceres, 2023).

A **Pew Research study** identified a high percentage of Gen Z and Millennials voice concern over climate change and support sustainable brands (Tyson et al., 2021). The **2023 US Sustainability Benchmark Report**, highlights the growing importance of sustainable brands to consumers and that consumers are switching brands based on this (Glow, 2023). By supporting sustainable water goals, companies can contribute to protecting community water supplies while providing products their consumers feel good about purchasing.

Water sustainability is a benefit that can be attained through water reuse. Water scarcity, droughts, and minimal water resources occur in many regions where beverage manufacturers develop manufacturing plants. These regions are advantageous because they enable beverage manufacturers to optimize supply chain logistics and access a wide consumer base. Leveraging water reuse practices can enable these manufacturers to develop businesses that are both sustainable and robust in these locations. The work of industry groups such as the Beverage Industry Environmental Roundtable (BIER) to develop best practices for operational procedures, equipment changes, and process modifications have helped beverage companies conserve water. As the beverage industry is extensive and continues to grow and expand each year, such development brings the opportunity for water reuse to enable continued, sustainable growth.

Agencies, non-profit organizations, and private companies continue to advance water reuse practices in the beverage industry. Examples of progress and success stories are described herein.

The National Blue Ribbon Commission for Onsite Non-potable Reuse Systems is one example of an effort undertaken to advance water reuse. In 2016, San Francisco partnered with the U.S. Water Alliance to formally convene this Commission. The Commission included representatives from public health agencies, water and wastewater utilities, and municipalities from 15 states, the District of Columbia, USEPA, the United States Army, and the cities of Toronto and Vancouver, Canada. Today, this group is supported by WateReuse, and its mission is to promote public health protection, science-based policy, a consensus-based approach, and honoring local issues and applications (US Water Alliance, 2023). As well as serving as a forum for collaboration and knowledge, the Commission conducts research to advance the implementation of onsite water systems. To help increase the adoption of onsite non-potable water systems, the Commission advocates for consistent policy frameworks across cities and states. However, the Commission has not adopted guidance for beverage recycling.

The San Francisco Public Utilities Commission (SFPUC) for Breweries was developed to advance water reuse practices in the brewing sector. Water plays a critical role in breweries, as it makes up a substantial proportion of the product volume and is used for numerous process applications. Much of this water is used for rinsing bottles and cleaning equipment. Treating and reusing this process wastewater can help breweries significantly reduce their water footprint. However, breweries receive limited guidance on how to safely reuse treated process wastewater onsite. In the City of San Francisco, breweries interested in process wastewater reuse looked to the SFPUC for help. The SFPUC developed guidance materials, including pathogen and chemical control strategies for process wastewater to be reused for tank and bottle rinses, floor wash down, boiler feed water, and as a source water for the beer. The guidelines include requirements for source water characterization, source control, treatment, and ongoing monitoring to ensure the water is safe for these uses. This approach is in line with the Hazard Assessment and Critical Control Point management system (discussed later in this white paper). Additionally, the guidelines are consistent with the California drinking water standards for chemicals, and with the risk reduction goals of the California drinking water standards for microbial pathogens. (San Francisco Water Power Sewer, n.d.).

WateReuse was established in 1990 and is the nation's only trade association solely dedicated to advancing laws, policy, funding, and public acceptance of recycled water. Representing nearly 250 water utilities serving over 60 million customers and over 200 businesses and organizations across the country, WateReuse has advocated for policies, laws, and funding at the state and federal levels to increase the practice of recycling water. To help advance water reuse in industrial sectors, WateReuse has recently established Industrial and Commercial Reuse and Onsite and Distributed Water Recycling Systems **Committees**, which convene quarterly to discuss opportunities and updates to advocacy, communications, education, and outreach within the sector (WateReuse Association, 2023). As the organizational leader on industrial water recycling, WateReuse administers numerous industrial water reuse initiatives, including the recent creation of the annual **Global Industrial Water Reuse Champions Award** and the development of an Industrial Water Reuse Specialty Conference, which will occur in 2024 (WateReuse Association, 2023).

WateReuse has established the Coalition for Water Recycling comprised of Fortune 1000 companies seeking to integrate the use of recycled water into their manufacturing processes. Among other efforts, the Coalition will be working to enact policies to promote industrial water reuse.

The Beverage Industry Environmental Roundtable (BIER), a technical coalition of global beverage companies, has driven sector actions and alignment on water stewardship and other environmental topics for nearly 20 years. Originally formed to develop consensus on water metrics, the group has worked to establish and communicate best practices on water efficiency, water stewardship and water reuse. They develop and publish **benchmarking reports** of water efficiency which show the industry continually improving (BIER, 2019). In addition, they have reported on **water circularity,** and **water stewardship** (BIER, 2023), (BIER, 2015) (BIER, 2019). BIER

Success Story: California Breweries

In California, several innovative breweries have implemented process wastewater reuse onsite to use water more efficiently. In addition to saving water, reuse treatment systems can also reduce the volume and strength of discharges to the sewer system, which can help breweries reduce their sewer bills and comply with local regulations. **Some examples** include the Seismic Brewing Company in Santa Rosa, California, USA which is recycling 95% of process wastewater generated onsite for applications such as cleaning and boiler feed water; Stone Brewing Company in Escondido, California, USA; and Lagunitas Brewing Company in Petaluma, California, USA (San Francisco Public Utilities Commission, 2021).

Success Story: Carlsberg

The Carlsberg Group received the Global Industrial Water Reuse Champions Award in October 2023 from WateReuse for their use of closed-circuit reverse osmosis technology and byproduct biogas to heat onsite facilities at its Fredericia, Denmark site. The system, which is part of their total water management treatment plant, recycles non-ingredient water used for cleaning and other industrial processes. They were able to reduce water consumption by 58.8 percent, or 500,000 cubic meters per year, and nearly eliminated the wastewater produced in its brewing operations (Cision PR Newswire, 2023).

members generally include companies such as PepsiCo with shared water stewardship values, such as PepsiCo, which they demonstrate publicly. For instance, PepsiCo recognizes the importance of water and maintains transparency to their goals and progress on pepsico.com:

"At all points along our value chain, water is a critical resource to our business, as well as for the health and safety of our employees and communities. Water irrigates the crops we use, is a key ingredient in many of our products and is essential to ensuring we meet the highest product safety and quality standards in our manufacturing facilities. Both PepsiCo and the communities in which we operate rely on clean sustainable **water supplies** and share a common interest in water protection and conservation" (PepsiCo, 2023).

PepsiCo is working to be **net water positive** by 1) "Increasing water efficiency in manufacturing and agriculture to mitigate risks to our manufacturing water supply," 2) "Partnering with leading non-governmental organizations (NGOs) to deliver nature-based solutions to strengthen and rehabilitate degraded ecosystems to improve the health of and protect high-risk watersheds" and 3) "Investing in distribution, purification and conservation programs to ensure safe drinking water for communities where we operate" (PepsiCo, 2023).

Success Story: Hillsborough County Public Utilities

Excess reclaimed water discharge to local surface waters was a regular occurrence in Florida. Rather than continue with this business-as-usual practice, WateReuse, Xylem, Tetra Tech, and GE collaborated to implement a pilot project at the Falkenburg Water Reclamation Facility that performed advanced treatment of reclaimed wastewater to achieve drinking water quality standards. In 2016, **WateReuse and Hillsborough County Public Utilities** worked with Special Hoperations to take it a step further (Wedeco, 2017). They began to provide this treated water to home beer brewers in the area, and even had a sampling of these beers at the 2016 WateReuse Symposium and at WEFTEC in 2016.

02 - A Framework to Advance Water Reuse in Beverage Manufacturing

As part of WRAP Action 5.7, our action leaders and partners convened to collaboratively assess barriers and opportunities for water reuse in beverage manufacturing. We found these barriers and opportunities fell into three major categories: stakeholder engagement, the regulatory environment, and treatment and technology issues. The results of our work, including key hurdles and near and extended-term solutions to address them, are presented herein.

2.1 - Stakeholder Engagement

As previously noted, we assumed water reuse practices occur inside the fence at beverage manufacturing plants; that is, we do not consider any interface points with municipal water supply or wastewater treatment facilities. We also assumed the treated water generated by a water reuse system is not used as an ingredient in consumer products in the near-term, but it could be used in this manner in the future. Stakeholders are defined as regulators, corporate personnel, water professionals, and consumers for the purposes of this white paper. Stakeholder engagement largely relates to communication and public perception in our discussion.

As water reuse opportunities evolve in the beverage space, terminology, naming conventions and definitions are impactful in informing stakeholder understanding, regulatory decision-making, and technical designs. Numerous organizations have sought to define water reuse terms in recent years; examples are as follows:

The USEPA created five descriptions of alternative sources of water for reuse, and nine descriptions of water reuse applications after thoroughly reviewing over 150 state reuse regulations and developing comparative summaries of the state regulations on REUSExplorer. These "source" and "reuse applications" descriptions provide a framework for increased clarity of discussion regarding water reuse.

REUSExplorer Terms

Below are REUSExplorer terms describing the "common vocabulary" based on state reuse regulations.

Water Sources	**A source of water for reuse purposes is any alternative water source that can help offset the demand for traditional freshwater supplies.**
Treated municipal wastewater	Treated wastewater effluent discharged from a centralized wastewater treatment plant of any size. Other terms referring to this source of water include domestic wastewater, treated wastewater effluent, reclaimed water, and treated sewage.
Onsite collected waters	Water sources generated within or surrounding a building, residence, or district. Other terms referring to this source of water include, greywater, blackwater, air conditioning condensate, and foundation water. Rainwater collected onsite is a unique source water.
Industry process water	Water produced during industrial and manufacturing processes. Other terms referring to this source of water include air handling condensate, boiler, cooling or wash water, and water generated during oil and natural gas extraction.
Stormwater	Precipitation that is collected from land or impervious surfaces at a district or regional scale (e.g., using a municipal storm drain) for the purpose of beneficial reuse. Precipitation collection at the building scale is classified separately under 'rainwater collected onsite'
Rainwater Collected Onsite	Precipitation that is collected at a building scale for the purpose of beneficial reuse within or surrounding the building. Precipitation collected at the district or regional scale is classified separately under "stormwater".
Reuse Applications	**A reuse application is the recycling of an alternative source of water that is adequately treated for its intended use.**
Potable water reuse	The use of highly treated recycled water for drinking water purposes. Includes the introduction of recycled water into an environmental buffer, such as groundwater aquifer or surface reservoir being withdrawn for potable purposes (indirect potable reuse), and the introduction of recycled water into a drinking water treatment facility or directly into a potable water distribution system (direct potable reuse).
Onsite non-potable water reuse	Water from onsite sources collected, treated, and used for non-potable purposes at the single-building or district scale. Excludes the use of recycled water from a centralized treatment and distribution system for landscaping or commercial uses (refer to "Water reuse for landscaping" and "Centralized non-potable reuse").
Centralized non-potable reuse	The use of recycled water for centralized non-potable reuse where the water does not derive from the same site where it is to be reused. Can include, but is not limited to, toilet flushing, dust control, soil compaction, fire protection, commercial laundries, vehicle washing, street cleaning, snowmaking, and other similar uses. Excludes onsite non-potable water reuse and the use of recycled water for agriculture or landscaping.
Water reuse for agriculture	The use of recycled water to land to assist in the production of both commercially and non-commercially processed food crops consumed by humans or livestock and non-food crops. Includes pasture for milking and non-milking animals, fodder, fiber, and seed crops, vineyards, orchards, ornamental nursery stock, Christmas trees, and silviculture. Excludes consumption by livestock, onsite non-potable reuse, and landscaping.
Water reuse for landscaping	The use of recycled water on land to assist in the irrigation of vegetation in residential and non-residential areas. Includes impoundments to store water for irrigation, ornamental vegetation, parks, school yards, sporting facilities (including golf courses), private gardens, roadsides and greenbelts, and cemeteries. Excludes irrigation of areas used for agriculture, commercial reuse applications, or any centralized onsite non-potable reuse.
Water reuse for consumption by livestock	The use of recycled water for livestock drinking water supplies. Excludes physical application of reclaimed water to pasture for milking and non-milking animals, forage crops used as animal feed, and land used for livestock grazing.
Water reuse for environmental restoration	The use of recycled water to create, sustain, or augment water bodies including wetlands, aquatic habitats, or stream flow. Includes groundwater or aquifer recharge for protection from saltwater intrusion, stream flow augmentation and wildlife habitat, and source water protection.
Water reuse for impoundments	The use of recycled water in an impoundment (body of water within an enclosure). This includes both unrestricted (use of reclaimed water in an impoundment in which no limitations are imposed on body-contact water recreation activities) and restricted (use of reclaimed water in an impoundment where body contact is restricted). Includes recreational impoundments, aesthetic impoundments, and ornamental impoundments with and without public access. Excludes landscaping, impoundments, and storage of recycled water intended for other specific reuse applications (e.g., for agricultural irrigation).
Water reuse for industry	The use of recycled water for industrial applications, often created at the industrial facility. This includes recycled water generated through onsite processes such as boiler water, cooling water, manufacturing water, and oil and gas production, as well as recycled water generated off-site and imported elsewhere for industrial reuse applications.

The United States Food and Drug Administration (USFDA) developed definitions pertaining to water use and potential; they are primarily listed in the **Current Good Manufacturing Practice regulation, 21 CFR 117 Subpart B**, and some are in associated guidance documents (National Archives, 2016). USFDA recognizes and uses some terms consistently with the USEPA REUSExplorer, particularly "industry process water".

WateReuse has developed a comprehensive **glossary of terms** covering uses and delivery methods, water reuse options, water types and quality, treatment technology, treatment processes and products, and state regulations (WateReuse Association, 2023).

Internationally, the World Health Organization (WHO) develops Food Standards Programs. The Codex Alimentarius Commission, established by the Food and Agricultural Organization of the United Nations (FAO) and WHO, is developing guidance that includes water reuse across various food industries. They tasked The Joint FAO/WHO Expert Meeting on Microbiological Risk Assessment (JEMRA) to develop microbiological guidance. JEMRA publishes an ongoing Microbiological Risk Assessment series, multiple of which focus on water. The **Series 33 meeting report** covers the safety and quality of water used in food production and processing, including guidance on fit-for-purpose water use within food manufacturing in Section 6.3. The report defines four categories for water use within operations:

1. Water used as ingredient,
2. Water used for intentional food contact applications, to include food contact surfaces,
3. Water used for unintentional food contact applications where it may unintentionally contact food or food contact surfaces, and
4. Water used for not-for-food-contact applications (FAO and WHO, 2019, pp57-58).

To drive consistency in terminology, first-use water, reuse water, along with subtypes of reuse water to include reclaimed water, recycled water, and recirculated water are also defined. A framework is defined in the form of a decision tree to determine the microbiological fitness of water for "Not for food contact applications" and the three "Food contact applications" (FAO and WHO, 2019, p61).

FAO and WHO Terms

The table below is adopted from TABLE 3. Definitions of various water types used in food operations, JEMRA Microbiological Risk Assessment Series 33 (FAO and WHO, 2019, p61).

First-use water	Potable water from an external source that can be used in any food processing operation.	
Reuse water	Water that has been recovered from a processing step within the food operation, including from the food components and/or water that, after reconditioning treatment(s) as necessary, is intended to be (re-)used in the same, prior or subsequent food processing operation. Below are three types of reuse water considered in this report.	
	Reclaimed water	Water that was originally a constituent of a food material, which has been removed from the food material by a process step and is intended to be subsequently reused in a food processing operation. Examples: water that was originally part of a raw material or food (e.g., tomato, sugar beet, milk, whey) and removed by a process step (e.g., sugar beet or tomato juice evaporated, and condensate water collected; condensate water from milk or whey evaporate; reverse osmosis permeate water from whey).
	Recycled water	Water, other than first-use or reclaimed water, which has been obtained from a food processing operation, or water that is reused in the same operation after reconditioning. Examples: brine, scalding water, and water for transporting or washing of raw materials, such as vegetables and fruits, in subsequent units, for which first-use water is used initially and then reused in previous units until it is used for cleaning of product coming from the field before being discarded or reconditioned.
	Recirculated water	Water reused in a closed loop for the same processing operation without replenishment. Example: a cooling or heating system in which water circulates, (e.g., condenser or pasteurizer cooling water).

The ILSI Research Foundation documented safe application of water conservation methods in beverage production and food processing, including a glossary for common analytical methods, engineering, and risk management processes relevant in water reuse applications. (Cotruvo, Bridgers, Cairns, & Cisneros, 2013)

The New York Water Environment Association (NYWEA) is developing a white paper on industrial wastewater treatment for beverage manufacturing, particularly breweries, distilleries, and cideries. This paper will summarize waste streams, treatment technologies, and regulatory hurdles for new manufacturers opening facilities in the State of New York.

BIER established guidance for improving water efficiency in manufacturing. In addition, they compiled a **benchmarking report** on industry wide water efficiency metrics (BIER, 2019). These reports contain basic definitions of water reuse and other relevant terms.

Campaigns have been used in adjacent industries, such as the municipal drinking water sector, to advance public acceptance and uptake of water reuse systems. For example, the work of WateReuse often included or centered around public perception and acceptance. Practitioners can learn from work by the municipal sector around potable reuse. Lessons from these experiences are transferrable to the beverage industry, including stories of how communities got to this point, practices that municipal agencies and water reuse professionals undertook to build public acceptance, and tactics, tools, and strategies to succeed.

WateReuse has developed numerous resources to help utilities build community understanding and acceptance of potable reuse, including **"Helping People Understand Potable Reuse: A Flexible Communication Plan"** and **"Model Communication Plans for Increasing Awareness and Fostering Acceptance of Direct Potable Reuse"** (WateReuse Association, n.d.), (WateReuse Association, 2015).

2.1.1 - Key Challenges: Communication and public perception

One key challenge inhibiting water reuse at beverage manufacturing plants relates to communication among regulators, corporate personnel, water professionals, and consumers. To date, no singular guidance document defining terminology and naming conventions specific to water reuse practices in beverage manufacturing has attained widespread stakeholder consensus. As multiple terms are relevant for beverage manufacturing, even simple ones can cause discussion over nuances of meaning. A noncomprehensive list includes terms such as drinking water, potable water, first-use water, source water, ingredient water, clean water, safe water, sanitary water, sterile water, water fit for purpose, process water, reuse water, recycled water, reclaimed water, recirculated water, treated water, and reprocessed water.

Differing terms or lack of similar terms used by regulators make conversations between industry and some regulators challenging. For example, when discussing water reuse in the context of permit development, beverage manufacturers may be required to identify the category of water to be used. Sometimes the options provided in the permit are not representative of process wastewater. Selecting the wrong option can have implications for use and requirements. For example, process wastewater is not the same as gray water or typical wastewater. Because there is not a globally or nationally aligned set of definitions universally understood, a food manufacturer may use the term reclaimed water in alignment with the WHO/JEMRA definition to mean water extracted from food, such as through evaporation to make juice concentrate. As another example, within **HEINEKEN's international operations**, reclaimed water refers to treated wastewater that undergoes further, extensive treatment using reverse osmosis or other means to generate water that can be used for process-related purposes (HEINEKEN, 2017). These definitions are different from reclaimed water definitions sometimes used by non-food agencies. For example, the **State of Washington Department of Ecology states** "Reclaimed — or recycled — water starts out as domestic wastewater (sewage) but is then treated and tested to use for specific purposes." "It is delivered through purple pipes to help alert construction workers, plumbers, and others that it is reclaimed water and not intended for drinking" (Dept. of Ecology, State of Washington, n.d.). Without a universal glossary of water reuse terms and naming conventions in the beverage industry, stakeholders experience misunderstandings from different meanings. The lack of consensual definitions drives material hurdles to the industry, such as permitting delays and missed opportunities to save water and reduce costs.

Another key challenge is public perception of water reuse by consumers. Consumers may need education to understand and have confidence that recycled water is safe, particularly when used as an ingredient. The beverage industry, including regulators, corporate personnel, and water professionals, are challenged to demonstrate and communicate safety to this important stakeholder group, as well as with one another. While common terminology is one key step, ongoing communications and uniformity with campaigns focused on water reuse issues, specific to the beverage industry, are necessary to help remove barriers to water reuse practices in this sector.

2.1.2 - Promising Solutions: Common vocabulary and campaigns

One promising solution is the development of a common vocabulary stakeholders can use to inform discussions related to water reuse practices in beverage manufacturing. A singular guidance document with widespread stakeholder consensus containing terminology and naming conventions specific to water reuse practices in beverage manufacturing would help clarify nuances of meaning. With common language, stakeholders can align their perspectives and have a common conversation as it relates to water reuse in beverage manufacturing.

The beverage industry has an opportunity to build on work by USEPA, WateReuse, FAO and WHO, and other entities to identify common water reuse terms, identify gaps pertaining to beverage manufacturing, and close these gaps. This level of granularity must go beyond industrial water reuse and address key issues specific to beverage manufacturing. The result would be a common glossary stakeholders can use to inform discussions and activities related to water reuse in this sector, such as the pursuit of permits, education and outreach, and development of treatment plant designs.

Another promising solution consists of planning new campaigns to educate stakeholders about water reuse in beverage manufacturing. Campaigns in adjacent sectors, such as the municipal drinking water sector, have helped advance the uptake of water reuse systems in those industries. Applying lessons learned from these campaigns to new ones customized for the beverage industry, particularly evolving to include social media, visitor's centers or facility tours, and other modern forms of stakeholder engagement, can help achieve similar goals. WateReuse's Annual Global Industrial Water Reuse Champions Award, Water Reuse Specialty Conference, and Coalition for Water Recycling are examples of modern initiatives to engage with industrial water reuse stakeholders and drive the uptake of water reuse practices in multiple industrial sectors. The inaugural Water Environment Federation (WEF) Circular Economy conference, held in July 2023, is another example of a recent endeavor designed to proactively engage stakeholders to discuss water reuse and other relevant issues. Efforts that are specific, customized, and narrowly focused on the beverage industry and engage regulators, corporate personnel, water professionals, and consumers would help normalize water reuse practices in the sector and pave the way for widespread use.

2.2 - Regulatory Environment

In the United States various regulators and regulations on federal, state, and local jurisdiction levels impact beverage production, water supply and wastewater disposal, and water reuse options at beverage manufacturing plants. The current state of the domestic regulatory environment pertaining to water reuse in the beverage industry is summarized herein.

USFDA is the primary regulator of the beverage product. In general, a foreign or domestic facility that manufactures, processes, packs, or holds human food for consumption in the United States has to register with USFDA under Section 415 of the Federal Food, Drug, and Cosmetic Act and is subject to the requirements related to preventive controls (primarily located in **Subpart C** and **Subpart G**) of the **Current Good Manufacturing Practice, Hazard Analysis, and Risk-Based Preventive Controls for Human Food rule** (21 CFR part 117; 80 Fed. Reg. 55908) (CGMP & PC rule), unless subject to an exemption (see 21 CFR 117.5 for exemptions). Broadly, water used in food processing must be safe and sanitary.

At the federal level, USEPA regulates the quality of drinking water supply through the Safe Drinking Water Act. Additionally, the Clean Water Act regulates discharges into Waters of the U.S. (i.e., many surface waters) which can include discharges from municipal wastewater facilities and many industrial facilities. These discharges are typically regulated via the National Pollutant Discharge Elimination System (NPDES) permit process. However, there are no federal level regulations implemented by USEPA specific to reuse of treated wastewater sources for potable or non-potable applications.

Many states have developed their own regulations or guidelines to aid in the implementation of beneficial reuse of treated recycled water from various types of wastewater sources. The USEPA has developed a comprehensive tool, called the "REUSExplorer," to enable clear comparisons of state-level water reuse regulations or guidelines and is searchable by source of water and reuse application. Beverage manufacturers intending to reuse a specific source of water (for example, industry process wastewater or onsite collected waters) may be subject to the state regulation if one exists. Locally, cities and counties may have additional requirements which affect the use of recycled water.

An important note is many beverage manufacturers operate globally and are therefore subject to regulations within international jurisdictions. Many of these regulations vary between countries. To account for this variability while protecting consumers and operating with consistent business practices, beverage manufacturers are incentivized to overlay local regulations with widely accepted risk assessment frameworks such as Codex Risk Analysis Framework and the **Hazard Analysis Critical Control Point (HACCP) management system** (USFDA, 1997). In addition, global beverage manufacturers may develop internal policies or guidelines establishing the most stringent applicable requirements (national, local, or company) on a global basis.

2.2.1 - Key Challenges: Lack of regulatory clarity and consistency of risk mitigation approaches

One key challenge inhibiting the uptake of water reuse practices in beverage manufacturing is the lack of clear regulations informing water reuse options at beverage manufacturing plants. As a result, there is limited understanding of which regulators must be engaged on water reuse projects in the beverage industry. Additionally, standards for water quality of water reused for beverage manufacturing have not attained regulatory consensus across agencies from local to federal levels. Without standards or other clear guidance, beverage manufacturers, water professionals and other stakeholders find it risky to develop water reuse systems. For example, when considering water reuse to generate source water at a beverage manufacturing plant, the lack of clear guidance makes it difficult to apply treated reused water in production processes or as an ingredient. On the wastewater side, permitting limitations may impede the ability of municipal wastewater treatment plants to accept concentrated waste streams, membrane reject, or sludge from a water reuse treatment system, or make it prohibitively expensive to do so. Beverage manufacturers contemplating onsite treatment may also encounter power, space, and other impediments that preclude further development of water reuse treatment systems.

Stakeholders endeavor to address these gaps at beverage manufacturing plants by overlaying hazard frameworks over applicable regulations. However, the regulations and hazard frameworks generally do not cross-reference one another and may not be understood by all stakeholders. Combined with the lack of defined water quality standards, developing technically efficient, cost-effective, and compliant water reuse treatment systems is difficult.

Another challenge relates to a lack of viable water reuse risk mitigation approaches available to beverage manufacturers. This issue becomes apparent when considering unregulated chemical hazards within a plant, because reusing water for non-potable purposes within a beverage facility falls outside of the scope of the Safe Drinking Water Act and many state regulations. USFDA regulations inform beverage manufacturing, but the lack of specificity surrounding “safe and sanitary” requirements makes it challenging to de-risk a water reuse application. As a result, the level of substantiation required to show regulators that unregulated chemicals have been sufficiently de-risked (shown to be safe and compliant) in a water reuse treatment application can be unclear. Furthermore, given the diversity of chemicals used in a beverage manufacturing plant, the logistics and costs required to identify and track many unregulated chemicals can be extensive.

The National Blue Ribbon Commission for Onsite Non-potable Reuse Systems and the City of San Francisco began developing guidance on this topic, including identifying and tracking key constituents such as pathogens as constituents of concern for regulatory purposes. These resources will help address this challenge, but additional guidance applying to beverage manufacturers in other jurisdictions may help advance water reuse practices more extensively in due course.

Despite this progress, the burden of proof may remain insufficient for certain categories of water at a beverage manufacturing plant, limiting water reuse opportunities. Categorizing water source types (process wastewater, wash water, and so forth), clearly defining the composition of these streams, and segmenting them for potential reuse within a beverage manufacturing plant may be a strategy to de-risk these streams for water reuse. However, there is limited guidance on this at present.

2.2.2 - Promising Solutions: Elevate hazard analyses to fill near-term regulatory gaps and identify low-risk water streams for water reuse in beverage manufacturing

Increasing stakeholder awareness of hazard analyses for water reuse in beverage manufacturing is a solution. This includes explaining the use of these analyses given the lack of clarity and consistency of regulations guiding water reuse on multiple levels. In the near term, hazard analyses could be elevated into standard industrial practices that help increase the uptake of water reuse practices at these facilities.

Hazard analyses are critical in beverage manufacturing. These analyses enable stakeholders to identify and understand what chemical and biological hazards exist at a plant and validate controls to mitigate these risks. In the United States, the HACCP framework is widely used to conduct hazard analyses. Regulators use the outcomes of these analyses and the associated controls identified to assess regulatory compliance. Beverage manufacturers operating domestically and abroad often use the Codex Risk Analysis Framework, an international framework, for these assessments. The Codex framework, which adopts HACCP principles, offers advantages for these entities, such as acceptance across multiple international jurisdictions, which leads to operational efficiencies within the organizations.

There is an opportunity to help practitioners understand how to apply HACCP principles to water reuse in beverage manufacturing to increase the quality of hazards analyses and to drive towards regulatory acceptance for water reuse projects. A HACCP flow chart for water reuse at beverage manufacturing plants is a first step to increase the uptake of water reuse practices in the near term.

Another promising solution is to identify low-risk water streams for water reuse at beverage manufacturing plants. These streams would be assessed using a widely accepted hazards analysis framework, such as HACCP, and the information made available to the broader industry to help encourage water reuse practices at facilities. This information would help stakeholders de-risk water reuse projects at beverage manufacturing plants and improve the pathway toward regulatory acceptance.

2.3 - Treatment and Technology

Within beverage manufacturing plants, treatment systems can remove constituents from process wastewater streams for beneficial purposes. Examples of current or potential water reuse applications at these facilities include the treatment of process wastewater for use in "high-end" applications such as bottle washing or washing of pipes and equipment, and "low-end" processes such as washing trucks or floors. Typical process wastewater streams that are candidates for water reuse applications may contain constituents which potentially present risks to health and safety, environmental quality, or infrastructure and equipment. Common constituents include particulates, nutrients, organic compounds, dissolved salts, trace chemicals, and pathogens.

A wide variety of conventional and advanced treatment technologies are available in the market to remove constituents for water reuse applications at beverage manufacturing plants. Typically, these technologies must be designed in a sequence known as a treatment train to achieve water quality goals that render a process wastewater stream usable for its intended purpose. Individual unit processes target specific constituents; other unit processes must be incorporated into the treatment train to enable comprehensive constituent removal. For example, reverse osmosis systems remove dissolved salts to very low levels but are not designed to filter particulate matter; pretreatment is necessary to remove particulates, preventing blockage of the membrane surface and inhibiting dissolved salt removal. Example technology families and their basic operating principles are summarized herein.

Physico-chemical treatment systems such as ultrafiltration membrane filtration comprise polymeric or ceramic filters operating under pressure to separate particulates, nutrients, and pathogens from process wastewater. For optimal performance, feed streams should contain extremely low concentrations of total suspended solids and organic compounds. Reverse osmosis and nanofiltration systems use semipermeable polymeric membranes to remove ions, molecules, and larger particles from process wastewater streams. Like ultrafiltration, these systems operate at high pressures. They generate a clean product stream and a waste stream containing elevated constituent concentrations. Electrodialysis reversal applies an electrical current across a stack of flat sheet semipermeable membranes to remove dissolved salts. Like reverse osmosis, this style of system produces a clean treated water stream and a waste stream with concentrated constituents.

Biological treatment systems such as biofiltration use microbes to oxidize, or break down, constituents in process wastewater. This system removes trace chemicals and organic compounds and produces sludge. Membrane bioreactors combine secondary and tertiary treatment into one step. Aerated tanks with beneficial microbes and submerged ultrafiltration membranes remove organic compounds, particulates, and nutrients. The bacteria break down these substances, and the membranes separate solids from liquids to generate a solids-free water stream and waste activated sludge.

Adsorption processes such as granular activated carbon generally involve sending process wastewater through a column or vessel filled with granules of activated carbon or other media. This media can adsorb constituents like trace chemicals from the process wastewater stream, removing them. The system must be monitored to prevent breakthrough, where constituents are no longer adsorbed to the media. Many adsorption systems produce minimal or no waste streams; however, the media must be removed and regenerated or replaced periodically to optimize performance.

Oxidation systems such as ozone and ultraviolet are primarily used for pathogen destruction. However, they can be designed to destroy trace chemicals. For optimal performance, the process wastewater entering these systems should contain low levels of turbidity and organic compounds. Neither system produces a waste stream.

In practice, each technology has tradeoffs affecting its suitability for use at beverage manufacturing plants. For example, reverse osmosis systems tend to be compact, which is advantageous for use in existing facilities where there is limited space available to install new equipment. However, as these systems operate under high pressure, they demand power input that may be costly in some locations. Stakeholders including utilities and water professionals must collaborate to devise systems that follow manufacturers' instructions to achieve treatment goals and comply with regulatory requirements.

Waste stream management is considered with logistics to permit a system and disposal of the waste material often impacts the types of technologies used at a beverage manufacturing plant. For instance, reverse osmosis systems produce brine, a concentrated salt stream that may not be acceptable at local municipal wastewater treatment plants. The holistic view of the operations and maintenance of the treatment trains, and the waste stream management should be evaluated for the local site options when planning for water reuse treatment. In states such as Texas, these concentrate streams may be disposed of via injection wells; however, this is not an option in many other areas of the country.

Monitoring systems must accompany a treatment system for process control to ensure the system consistently and reliably removes constituents. This efficacy is important to stakeholders for many reasons. For example, beverage manufacturers must ensure operations staff are protected from potential health and safety exposure. Regulators are focused on identifying and tracking regulated constituents to ensure treatment systems are compliant. Real-time monitoring is therefore critical to ensure the effectiveness of treatment systems at beverage manufacturing plants.

Stakeholders have developed an extensive body of knowledge related to treatment technologies and monitoring systems. Examples include industry groups such as WateReuse, and the Water Environment Federation and conferences, such as the Food and Beverage Environmental Conference and the International Water Conference, which offer libraries with technical materials to help educate the public about the state of the art and successful applications.

2.3.1 - Key Challenges: Unclear design criteria and waste stream constraints

As discussed previously, many treatment approaches and monitoring systems are available in the market. Importantly, technology is usually not a limiting factor for water reuse at beverage manufacturing plants. However, other challenges driving treatment and monitoring selection must be addressed over near and extended time horizons to enable water reuse to be implemented more broadly at beverage manufacturing plants. These challenges include a lack of clarity of design criteria and waste stream constraints.

The first key challenge is a lack of clarity of the design criteria needed by water professionals to develop treatment systems for water reuse at beverage manufacturing plants. Design criteria includes information necessary to develop complete treatment solutions, such as the type of process wastewater stream available for treatment, their quantities and qualities, and the achievable treated water composition. The latter is typically set by regulatory requirements, such as discharge permits and regulations that protect public health and the environment. Equipment manufacturers also set quality targets to enable optimal operation of their products, including treatment and maintenance schemes. As discussed previously, no singular set of regulations establish treated water composition requirements at beverage manufacturing plants. Risk assessment frameworks like HACCP can help water professionals identify vulnerabilities within a treatment system and design the system to address them. However, the use of HACCP at beverage manufacturing plants for water reuse systems is not widely used or understood. These issues result in unclear design criteria for water reuse treatment and monitoring systems, and subsequently less incentive for end users and engineers to commission and design these systems at beverage manufacturing plants.

Waste management is another key challenge facing beverage manufacturers contemplating water reuse at their plants. As noted previously, treatment technologies produce waste streams such as concentrated brine and sludge. These waste streams often contain biological and chemical constituents which are challenging to dispose of for regulatory or technical reasons. From a regulatory perspective, beverage manufacturers may encounter difficulties obtaining disposal permits due to ingredient disclosure issues or chemical concentrations. Technically, the waste streams can be substantial in terms of flow, volume, or load, and municipal wastewater treatment plants may be unable to accept them. Beverage manufacturers may lack space, energy, financial, or other resources to construct evaporation ponds, crystallizers, or zero-liquid discharge systems on their sites, and/or the means to properly dispose of solid waste. Lack of disposal options limits the propensity for beverage manufacturers to seek water reuse solutions as a result.

2.3.2 - Promising Solutions: Industry design guidance, decision tools, and demonstration plants

One promising solution is to elevate the HACCP framework within the beverage industry, as a guide for water reuse treatment designs, particularly in the absence of clear regulatory-driven design criteria. HACCP informs regulatory decision-making, such as the granting of discharge permits. While the use of HACCP at beverage manufacturing plants is well-understood for other processes, it has not been widely implemented for water reuse. HACCP can help identify vulnerabilities within engineering designs and validate reliability. The outputs of HACCP, when applied to a water reuse treatment design, can enable water professionals to optimize functionality, mitigate risks, and provide the substantiation required to secure permits or other regulatory acceptance. Helping stakeholders understand how to apply HACCP to water reuse at beverage manufacturing plants may make it possible for widespread acceptance of water reuse solutions in the future.

Another promising solution is to develop technical decision tools to help inform and optimize technology selection for water reuse systems at beverage manufacturing plants, given the lack of regulatory clarity and stakeholder engagement issues in the sector. These tools include guidance for water reuse applications at beverage manufacturing plants. This would identify potential streams (sources) that could be treated for beneficial purposes (applications) at a beverage manufacturing plant, the key chemical and biological hazards associated with them, and the technologies for use on each source. The hazards identified are like those found when applying the HACCP framework to these sources. Guidance would include a list of technologies to address these risks and identify the constituents which would be removed, or not removed.

Finally, developing intentional water reuse demonstration plants at beverage manufacturing plants is a promising solution to explore the ideas herein and share best practices with the broader industry. These projects would enable stakeholders to understand the full lifecycle of decision-making that informs the development of water reuse systems, including key steps to obtain regulatory approval, select technology, design, optimize, and de-risk systems, and commission them.

Important to note is demonstration and full-scale plants have been developed at beverage manufacturing plants around the world. For example, HEINEKEN developed an effluent reclamation plant designed to reclaim and recycle water used in production processes in **Sedibeng, South Africa** (HEINEKEN, 2017) and in **Indonesia and Mexico** (HEINEKEN, 2020). However, given nuances within the industry related to the type of beverage being produced, size of facility, and other factors, intentional demonstration plants matching water reuse applications to a specific goal (for example, converting bottle washer waste to a usable stream within the manufacturing process) would help ensure the outcomes are useful for the beverage industry and can advance water reuse within it holistically. The technical decision tools noted previously could help beverage manufacturers identify compelling water reuse applications that align with their corporate objectives and triangulate them with projects that other manufacturers have completed globally. Where gaps exist, demonstration plants could be pursued to generate the data and experience required to enable water reuse to be developed and sustained at full scale.

03 - Priority Challenges and Recommended Actions

Priority challenges, promising solutions, broad tactics, and a suggested time horizon for implementation are below. We have assumed that the near-term time horizon is between one and three years, medium-term is between two and five years, and long-term is five years or more.

Priority Challenges	Promising Solutions	Tactics	Time Horizon
Water reuse terminology is inconsistent between markets and applications.	Review existing terms, identify gaps, and close gaps.	Create a glossary of terms for stakeholders in beverage manufacturing.	Near term
HACCP is used to inform regulatory decision-making. Its use in beverage manufacturing is well-understood for other processes but has not been widely implemented for water reuse.	Help practitioners understand how to apply HACCP principles to water reuse in beverage manufacturing, to enable regulatory acceptance.	Create a flow chart of how to proceed with HACCP for water reuse in beverage manufacturing.	Near term
Public perception informs corporate perception, and subsequently regulatory acceptance, of water reuse in beverage manufacturing.	Demonstrate and communicate the safety of water reuse to increase stakeholder acceptance	Organize specific, customized, and narrowly focused campaigns, such as a summit, to engage regulators, corporate personnel, water professionals, and consumers on water reuse in beverage manufacturing.	Medium term
Waste stream management inhibits the uptake of water reuse at beverage manufacturing plants. Regulatory gaps make it difficult to set a design basis, which water professionals need to design treatment systems	Develop selection criteria to narrow down design, treatment, and monitoring systems options at beverage manufacturing plants.	Develop a technical guidance document to inform treatment and monitoring designs.	Medium term
Unclear understanding of water reuse decision points inhibits the uptake of water reuse systems at beverage manufacturing plants.	Help stakeholders understand the full lifecycle of decision-making that informs the development of water reuse systems, including key steps to obtain regulatory approval, select technology, design, optimize, and de-risk systems, and commission them.	Commission intentional demonstration plants to test ideas and inform industry best practices.	Medium - Long term

04 - Go Forward Plan

Water reuse offers a compelling opportunity for the beverage industry to address important water issues at beverage manufacturing plants. These issues are complex, as they include stakeholder engagement, regulatory, and treatment and technology components. However, they can be broken down into actionable next steps that can help advance water reuse practices at beverage manufacturing plants in due course. These steps and their associated time horizons include the following:

In the near term (one to three years), developing a glossary of terms pertaining to water reuse in the beverage industry and a flow chart of how to proceed with HACCP for water reuse in beverage manufacturing can help stakeholders speak a common language and validate water reuse projects at beverage manufacturing plants. This may help drive uptake of water reuse at these facilities, particularly in cases where treated water is not used as an ingredient.

In the medium term (two to five years), industry-specific campaigns such as a water reuse summit for the beverage industry can help stakeholders normalize water reuse practices at beverage manufacturing plants. Developing a technical guidance document with low-risk water sources, water reuse applications, chemical and biological hazards, and technologies to address them could help stakeholders navigate regulatory gaps and obtain sound technical guidance to develop reliable water reuse systems.

In the medium to long terms (two to five or more years), commissioning intentional demonstration plants can help stakeholders clarify critical decision points to develop water reuse systems. It can also inform industry best practices that support the broader community on future projects.

The Action Partners intend to convene in 2024 to review the recommendations herein, share results with the broader community, and determine next steps (including detailed tactics and ownership of tasks) to help advance water reuse in the beverage industry.

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