A sustainable approach to managing high-strength wastewater

How food & beverage processors can reduce costs and improve sustainability with new microbial fuel cell technology.

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Wastewater management today

Wastewater is almost never a primary consideration for food and beverage (F&B) processors, and it is only as they encounter difficulties with the receiving utilities that it becomes a management priority. Proactively managing wastewater provides a competitive edge because it avoids production risks, aligns with sustainability goals and a positive brand image and reduces operational costs. However, there is no one-size-fits-all approach to wastewater management. The wastewater profile, flow and costs vary greatly, even within different facilities of the same company. The answer for the best way to manage wastewater is usually, “It depends”.

Discharge to sewer

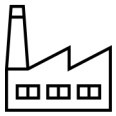
In the case where F&B plants can discharge to the publicly owned treatment works (POTW), rates will vary greatly depending on the individual municipality’s economics. Most POTW’s were built for residential sewage and are challenged by the wastewater produced during food or beverage processing. Their primary purpose is to treat residential sewage, and when F&B plants strain their treatment or force unpermitted discharges, the POTW will charge high surcharges (sometimes costing millions of dollars per year) or require the processor to find an alternative (such as trucking). They can also place limitations on production and expansion or require pretreatment, which can be costly, labor intensive and require high chemical usage. The growth in industry during COVID, coupled with reduced infrastructure spending has made the risk of price increases even higher.

Trucking

Trucking may become necessary when the plant cannot meet their permit discharge levels or when their existing treatment facility cannot handle the loads. It can be logistically difficult (multiple trucks coming in and out multiple times per day), expensive, and unsustainable. The corresponding greenhouse gases from trucking are counter to F&B companies’ sustainability initiatives. As production volumes increase, the economics will force F&B plants to consider onsite industrial pretreatment.

Onsite treatment

Either aerobic or anaerobic treatment could be used depending on the effluent profile, available land and surrounding community. It is costly to install and operate, requiring high energy demand, nutrient dosing and an onsite wastewater operator. Most F&B facilities prefer to focus on their core business and avoid installing onsite treatment until other options have been exhausted. With anaerobic systems, biogas can be captured and burned, offsetting energy requirements for the plant, but this requires infrastructure to clean the gas, as well as safety requirements for methane generation.



Off-grid

In small towns or rural areas, wastewater management needs to be considered during the design phase. One facility that we are working with was informed that they would require an onsite treatment system to comply with state, county and local discharge requirements, as they had no utility to discharge to. When they started looking at options to treat their wastewater, standard treatment systems were prohibitively expensive and came close to shutting down the entire business.

Wastewater terms demystified

Biological oxygen demand (BOD) or Chemical oxygen demand (COD)

Biological oxygen demand (BOD) is the amount of organic carbon (often sugar) that is biologically digested over a 5-day period. Chemical oxygen demand (COD) is the total amount of carbon in the wastewater that can be chemically or thermally reacted with oxygen. COD can be measured in real-time with in-line sensor; however, BOD is a more difficult test to automate.

BOD/COD levels will vary depending on several factors, including the type of product(s) produced, ingredients used and whether the high-strength streams are separated out. In a food processor, BOD can be up to 150,000 mg/L, or 1,000 times higher than residential sewage. These ultra-high strength streams are usually the most expensive part of wastewater management, and result from discarded product or the first 1-2 rinses from a Clean-In-Place (CIP) process. Even in cases where the average BOD of the plant effluent is relatively low, point source discharge could generate ultra-high strength waste streams that require dilution and/or pre-treatment.

High-strength or “ultra” high-strength

Utilities consider high-strength to be anything over 300 mg/L BOD, while technology providers consider high-strength to be anything over 1,000 mg/L and ultra or super high-strength to be over 10,000 mg/L BOD. The super high-strength wastewater streams tend to only be 10%-20% of the total wastewater generated in a given production process. However, this small volume can pose large problems to small municipalities that may not have the capacity for these ‘plugs’. As more and more companies decrease their overall water consumption during manufacturing, these concentrated volumes become more problematic.

Fats, Oils and Grease (FOG)

Fats, oils and grease from the production process is one of the biggest challenges to sewer lines because it clogs the pipes and can create buildup that obstructs water flow. As a result, food processing plants need to have a pretreatment system or Dissolved Air Flotation (DAF) to remove FOG before discharging into municipal pipes.

Total suspended solids (TSS) and Total dissolved solids (TDS)

TSS is a measure of the concentration of non-dissolved solids in the water, while while TDS is a measure the inorganic salts dissolved in the water.

Using BioElectrochemical systems

Microbial fuel cells (MFC) have long been explored as a waste-to-energy approach that provide energy-neutral wastewater treatment. Until recently, most MFC technologies were not commercially scalable and addressed a small part of wastewater treatment.

Aquacycl® has developed the first commercially viable microbial fuel cell for ultra-high strength wastewater treatment. Our BioElectrochemical Treatment Technology (BETT®) is the only cost-effective, small footprint system for very high-strength streams, treating organic wastewater with chemical oxygen demand (COD) values up to 300,000 mg-COD/L, total suspended solids (TSS) up to 30,000 mg-TSS/L and a wide range of temperature profiles (10ºC – 50ºC).

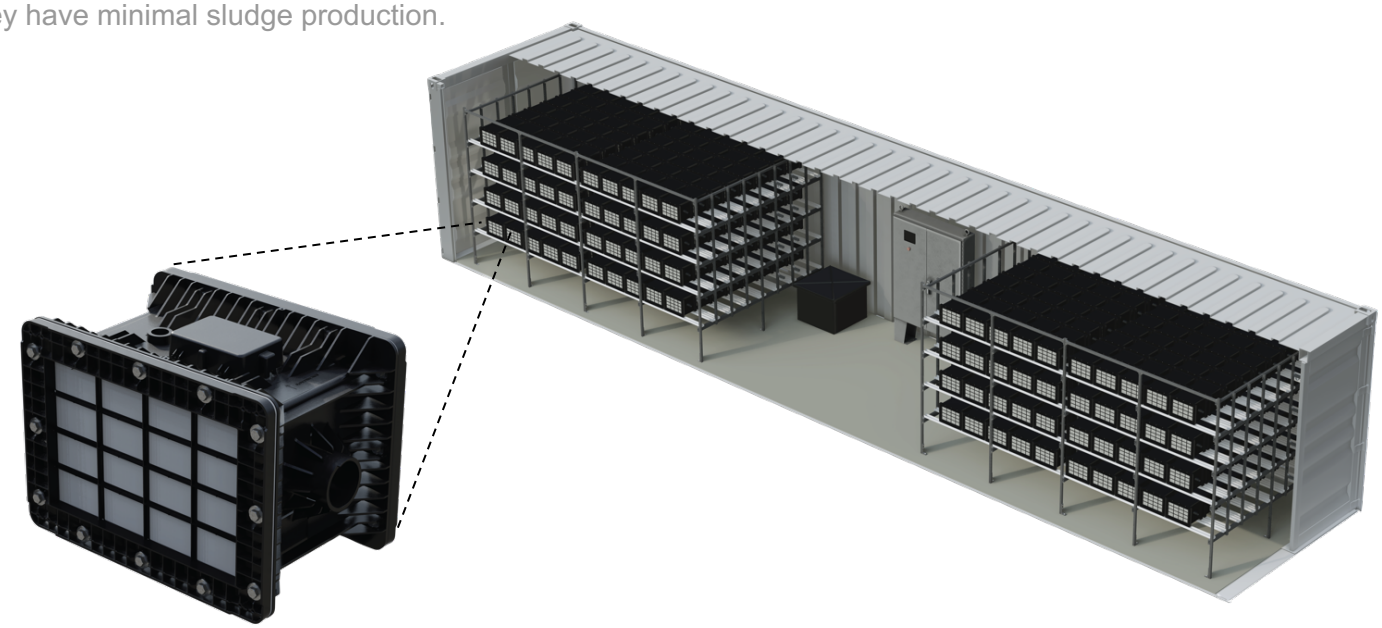
BETT uses locally-sourced bacteria to break down the carbon-based organic matter in the wastewater. As they “eat” the organic material, they use the conductive surfaces to breathe, releasing electrons during the process of respiration. By increasing the rate that electrons are taken away, treatment rate is significantly increased, taking hours instead of days or weeks, with the added benefit of effectively “starving” the microbes so they don’t overgrow, meaning that they have minimal sludge production.

BETT reactors are the size of a standard car battery and are placed in a series of treatment trains housed in shipping containers, creating a modular and flexible approach to wastewater management. Multiple reactors are placed in hydraulic series to remove carbon, and multiple reactor treatment trains are used to accommodate wastewater volume.

By adding more reactors in a treatment train, and operating multiple treatment trains, the BETT reactors can be used to remove up to 95% of organics with flows between 2,500-10,000 gpd.

BETT enables water reuse when combined with complementary post-treatment technologies. BETT is remotely monitored and controlled, which minimizes onsite operator time. The BETT systems are significantly more energy efficient than any other technology on the market because of low-pressure and low flow rate operations that reduce horsepower requirements.

Aquacycl has been working with **sugar refiners, confection, and beverage** companies to identify opportunities for reducing wastewater management costs by 20-60% relative to current practices.



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How BETT® systems are applied

The BioElectrochemical approach offers many benefits including low-cost operation, electricity offsets and energy efficient operations, low chemical addition and/or no nutrients dosing, small footprint, negligible biomass production, no environmental impact and reliability due to fixed-biofilms in the system. Companies can use BETT systems as pretreatment in the following ways:

treat

300,000

mg-COD/L

without dilution

1 Industrial pretreatment to onsite treatment

For companies that already have onsite wastewater treatment BETT systems make all downstream treatment more efficient. We treat small volumes of highly-concentrated wastewater, making aerobic and anaerobic wastewater systems more efficient. As a pretreatment step, the BETT systems normalize the feedstock, reducing adverse impacts of production variability, pH, and temperature.

2 Industrial pretreatment to discharge to utilities

For companies that are paying high surcharges or trucking costs, BETT systems can treat wastewater to levels that can be discharged to sewer without additional fines, allowing companies to maintain compliance with their permit limits. For processors located in urban areas where it is not feasible or economical to install onsite treatment, the only option has been to truck offsite as the wastewater is often too concentrated to discharge to the utility. BETT systems have a small footprint (either 20 or 40-foot standard shipping container) and are used as pretreatment to reduce COD, TSS, color and nitrogen.

3 Distributed wastewater treatment

BETT systems can be used with complementary technology to enable onsite wastewater treatment where no sewer connection is available. Combined with complementary technologies, BETT can enable water reuse on site.

Case study: confectionery

The Wastewater Challenge

A confectionery company faced challenges with process wastewater with an extremely high sugar content. This specific waste stream (“sugarwater”) required pretreatment or dilution prior to land-application and could not discharge to the onsite aerobic treatment facility due to carbon toxicity issues that would occur.

Aquacycl installed a fully automated and containerized 12-reactor demonstration unit to continuously treat 160 gpd of the sugarwater and enable a clear understanding and cost model for how BETT systems could be applied at full-scale for sugarwater treatment.

System COD removal and power production were monitored during the demonstration. The inflow sugarwater COD ranged from 30,000 to 300,000 mg/L under continuous flow conditions. Batch operations were also required corresponding to production shutdowns associated with holidays and other facility operations.

Results

The BETT Demo unit accomplished an average COD removal of 18,377 mg/L in a 4-hour hydraulic residence time with only 12 BETT reactors in hydraulic series (footprint of a 12 car batteries).’

The COD removal capacity of the system ranged from 2,200 mg/L to 50,000 mg/L in 4 hours, depending on the loading being sent to the system in a 4-hour period. The system exceeded agreed milestones and demonstrated ability to quickly recover even after multiple production shutdowns. The system demonstrated low sludge production, with less than 1% of the COD removed converted into secondary biomass (secondary sludge).

The electricity was generated as DC power, with no intermediate methane production

These results showcase how microbial fuel cells can be used for treatment of high-organic wastewaters.

Higher COD removal than other technologies

95%

COD removal

4

Hour treatment time

10x

Higher COD removal than other technology

High removal rates

BETT systems are the only technology that can handle up to 300,000 mg-COD/L. They remove up to 95% of Chemical Oxygen Demand (COD), 80% of Total Suspended Solids and sulfur.

Reduce screening and pretreatment

BETT systems can handle wastewater up to 30,000 ppm TSS, a ten-fold increase compared to traditional systems. Aquacycl's patented micro-aeration technology removes total sulfur. The unique capacity to address high TSS and total sulfur helps to eliminate chemical addition and operational complexity.

Reduces treatment times

The BETT system regulates microbially generated electrical current to accelerate treatment rates – the more electricity produced, the faster the microbes consume the organics in wastewater. Depending on the wastewater composition, BETT systems can treat wastewater in hours, compared to days or weeks in a conventional anaerobic digestor.

Minimal sludge management

BETT systems generate minimal sludge, requiring sludge removal only once per year, or once per quarter. This is compared to traditional systems that require costly sludge removal.

Reduce operating costs

F&B companies spend millions on trucking and sewer surcharges that drive up operating costs and are subject to rate increases and permit renegotiation. Unless the company invests millions in an onsite wastewater treatment facility, these costs can be out of their control.

Aquacycl's BETT system reduces operating costs in the following ways:

Reduce trucking costs and sewer surcharges

BETT systems can eliminate these costs completely by treating the wastewater to a level that can be discharged to sewer without BOD and TSS surcharges.

Reduce risk through guaranteed performance

BETT systems have guaranteed performance, allowing customers to maintain permit compliance and discharge requirements. They reduce the risk of utility price increases and permit level changes. The agreed terms provide fixed operational costs for treating wastewater that is not subject to utility rate increases.

Reduce chemical and energy costs

Anaerobic digesters require careful monitoring and frequent nutrient dosing to keep them operating at maximum efficiency. BETT systems can reduce chemical requirements because they don't require any added nutrients. They generate direct electricity and are designed to require low power.

Remote monitoring and control

Each BETT reactor is remotely monitored and controlled to allow real-time performance and troubleshooting. This eliminates the need for a full time trained on-site operator

Reduce capital costs

Building on-site wastewater treatment facilities can cost millions of dollars. They were traditionally designed based on wastewater volume - more volume meant a bigger tank and pump and footprint.

When BETT systems are installed as part of the treatment design, they can increase the efficiency of the entire system design and reduce capital costs.

Small footprint

Since the BETT systems are treating low-volumes of very concentrated wastewater, the footprint is up to 90% smaller than conventional AD. This can be a key design consideration for companies that are space constrained.

The reactors are modular and stack together like LEGO's® inside a 20 or 40 foot shipping containers. The number of reactors depends on three factors:

- Volume treated
- Composition of wastewater
- Target effluent quality

No CapEx

BETT systems can be offered on an entirely service/performance basis, meaning that there is no capital expenditure and immediate savings can be realized.

More efficient system design

For companies that are designing new wastewater treatment systems, or upgrading existing infrastructure, incorporating BETT as a pretreatment step enables lower CapEx and OpEx because all down stream processes can be sized smaller and/or will operate more efficiently, with less energy and chemical consumption.

Achieve sustainability goals

Today, 80% of wastewater that is generated globally is discharged to the environment with minimal treatment or no treatment at all. These actions contaminate freshwater resources and limit access to clean water.

Water usage is an important sustainability initiative for F&B companies. The water intensity has a direct impact on the bottom line and surrounding community, and all major F&B companies have pledged to increase water efficiency. As water intensity decreases, high-strength wastewater can become more difficult to treat.

Sustainable Development Goals

Many companies have pledged onto the United Nations Sustainable Development Goals

BETT systems directly address Clean Water and Sanitation. We were started with a mission of Sanitation for All.

Reduce energy consumption

BETT systems are low-power compared to other treatment options and can be used to reduce energy consumption downstream. They are the first commercially viable microbial fuel cells that use use natural electrogenic bacteria to generate direct electricity.

Zero-liquid discharge

Aquacycl can work together with other technologies to make new molecular water and allow water reuse. Treated water can be reused for HVAC or irrigation when BETT is coupled with other post-treatment technologies.

Joshua Tree Brewery wanted to expand into a larger operation to meet demand, but the city required that they treat their wastewater to irrigation-quality standards before allowing them to open. Aquacycl's BETT system worked with complementary technology to provide clean water in accordance with the county's requirements..

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Improve anaerobic digester efficiency

Conventional anaerobic digesters (AD) require highly-controlled operational parameters (temperature, pH, mixing, minimal wastewater variation) and nutrient dosing to efficiently treat wastewater and produce meaningful methane. Any change in the production process or ingredients can lead to changes in wastewater that may create toxicity events in the digester. All of these factors may result in many AD systems not achieving the initial design objectives.

Aquacycl's BioElectrochemical Treatment Technology (BETT®) system can act as industrial pretreatment to make AD significantly more efficient and reliable.

Increases methane generation

BETT accelerates the hydrolysis of complex carbon sources and enhances the fermentation rates to generate the smaller volatile fatty acids that the methanogens prefer.

The processes also normalizes the feedstock, reducing adverse impacts of production variability, pH, and temperature to the AD. By reducing the complexity and variability of the carbon chains and other parameters, the AD will operate more consistently and with higher methane production.

Reduces toxicity events

BETT systems reduce toxicity events with AD by normalizing the feedstock. Toxicity events at an AD can take months for the microbes to recover, which can cause discharge that exceeds permitted levels, or even force production to stop.

A major brewery was experiencing toxicity events at their on-site anaerobic digester. Changes to their recipe resulted in small quantities of very high-strength wastewater that upset the treatment system for the entire brewery.

Enables process variability

Any change in the manufacturing process ends up in the treatment system. This means that line changeovers, ingredients or any other process variation will upset the balance in the AD. Using BETT reactors as a pretreatment step normalizes the feedstock (pH, temperature, flow and composition), improving the efficiency of AD.

Decreases treatment times

By breaking COD into smaller carbon chains, BETT reactors help AD reduce treatment times. The simpler Volatile Fatty Acids will decrease treatment time because they are easier for the microbes to break down in the AD.

Improve aerobic treatment efficiency

Reduce sludge management

Sludge removal can be a costly operating expense, and aerobic treatment generates high quantities of sludge. When BETT systems are a pretreatment step, they remove most of the COD, making aerobic polishing easier and faster. BETT systems require sludge removal only once per year.

Reduce energy consumption

Aerobic treatment requires large amounts of energy because air must be continuously circulated through the tanks. BETT systems reduce the energy consumption by removing the complex carbon chains, making it easier for aerobic systems to break down.

Technology comparison

	Aquacycl BETT®	High Rate Anaerobic Digestor	Membrane Bioreactor
COD concentration (mg-COD/L)	**1000 - 300,000**	3,000 - 30,000	140 - 10,000
Maximum TSS concentration (mg/L)	**30,000**	300	300
Maximum FOG concentration (mg/L)	**300**	50	50
Treatment time (HRT)	**~4 hours**	8 – 16	~6 hours
Organic loading rate (g-COD/L/day)	**10 – 300**	0.4 – 25	0.5 - 2
Energy consumed (kWh/lb-COD)	**0.05 – 0.09**	0.2 – 0.3	0.5 – 0.9
% Sludge (Biomass / COD treated)	**0.7%**	10%	60%
pH range	**5 - 9**	6.5 – 7.5	6.5 – 7.5
Operating temperature	**50 – 120 °F**	90 – 105 °F	86 – 92 °F

> Without the BETT system, the city wouldn't let us open our brewery because they didn't have the infrastructure to treat the high-strength wastewater. We looked at off-the-shelf systems, but they weren't affordable for small businesses. Aquacycl's system is great for the environment, and we are impressed by the user-friendliness of the system, customer service and affordability.
>
> – **Dario Guerra, Joshua Tree Brewery**

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