Comparative Analysis of GHG Emissions in F&B Wastewater Treatment

Most industrial food and beverage (F&B) wastewater is a result of clean-in-place (CIP) processes that are required for ensuring product quality and FDA compliance. Each CIP process may include up to 5 rinse cycles per product line. The first rinse cycle results in 80-90% of the chemical oxygen demand (COD) concentration associated with industrial discharge. Subsequent CIP rinse cycles discharge mostly clean water and represent majority of discharge volume. Therefore, 20% of the total discharge volume represents 80% of the overall COD concentration, and a majority of wastewater management costs. Large commercial beverage manufacturers may discharge up to 300,000 gallons per day (gpd) per facility with COD values ranging between 3,000 mg/L and 6,000 mg/L. This results in total discharge loads of 3,400 to 6,800 kg-COD/d that may be discharged to sewer or hauled offsite for landfill or alternative treatment. In rare cases, F&B facilities may have onsite treatment plants using aerobic or anaerobic treatment processes.

Crush processes at beverage facilities add additional COD discharge and are managed as separate streams that discharge directly to sewer or are hauled offsite and landfilled. Crushing operations recover the plastic and aluminum packaging from damaged or expired products, and the product that is released from the packaging (e.g. juice, soft drink, protein beverage, energy drink, etc.) is sent to drain or storage tank. A standard crushing operation may generate 5,000 to 10,000 gpd of wastewater that has a COD concentration near 120,000 mg/L. This results in a loading of 2,280 to 4,560 kg-COD/d that may be discharged to sewer or hauled offsite for landfill.

Municipalities specifically regulate biological oxygen demand (BOD). The ratio between BOD and COD is typically 0.625 for F&B wastewaters. The BOD discharge is monitored and permitted for every commercial facility operated within a given municipality that provides sewer services. Industrial customers are permitted to discharge a capped value of kg-BOD/d (or lb-BOD/d) per facility and are charged as a cost per kg-BOD (or cost per lb-BOD) per month. Sewer surcharges can range from $0.01/lb-BOD and $1.50/lb-BOD depending on municipality and typically escalate between 4% and 8% per year. Discharge permit limits are uniquely governed per customer and per municipality throughout.

The discharge from large F&B production facilities results in high energy costs to the municipality given the energy required to maintain treatment capacity at the centralized municipal treatment facilities.

Centralized municipal treatment facilities all use some form of activated sludge process (aeration-based biological treatment), which requires between 0.7-1.0 kWh to remove 1 kg of BOD. In California, 1 kWh of electricity generation is equivalent to 0.331 kg of carbon dioxide equivalents (CO_2e). The use aerobic technologies results in the production of secondary sludge, which must be hauled offsite and landfilled. Roughly 45% of the BOD treated during activated sludge processes is converted into waste sludge. Sludge production and energy consumption result in significantly high GHG emissions for aerobic treatment processes.

Some municipalities and F&B producers may also use anaerobic digestion to complement aerobic processes and recovery energy in the form of biogas. Anaerobic digestion is a batch process, requiring 3 to 15 days to treat a single batch. This results in very large installations that have a high capital and operational cost. Anaerobic digestion also produces secondary biomass that must be landfilled. Approximately 10% of the BOD treated during anaerobic digestion processes is converted into waste sludge.

Emissions savings to the municipality and low-carbon energy generation at the customer site is enabled using Aquacycl® BioElectrochemical Treatment Technology (BETT®). Both technology benefits yield significant reductions in GHG emissions relative to conventional activated sludge and anaerobic digestion treatment processes.

Tables 1 and 2 show comparative operational results for activated sludge, anaerobic digestion and BETT all treating 22,500 gpd with a starting COD of 100,000 mg-COD/L and removing 95% of carbon (removing 95,000 mg-COD per day). In all cases, BETT performance factors are significantly improved relative to conventional methods.

Table 1: Technology performance and methane emissions relative to secondary biomass (sludge) production for a flow of 22,500 gpd and 95% COD removal (8,123 kg-COD removed per day)

Technology	COD removed (mg/L)	COD removed (kg/d)	BOD removed (kg/d)	Biomass produced (kg/d)	% Biomass/ COD treated	Volume sludge assuming 8% sludge (gal)	Trucks per month (truck volume 4000 gal)	Landfill CH4 Emmissions (ton-CH4/yr)
Aerobic	95,000	8,123	5,077	3,655	45.0%	12,023	60.12	328,961
Anaerobic	95,000	8,123	5,077	812	10.0%	2,672	13.36	73,103
BETT	95,000	8,123	5,077	414	5.1%	1,363	6.81	37,282

Table 2: Technology performance and GHG emissions relative to energy consumption and production for systems treatment 22,500 gpd and removing 8,123 kg-COD per day.

Technology	COD removed (kg/d)	BOD removed (kg/d)	Energy Consumed (kWh/kg-COD)	Power Consumed (kWh/d)	Energy Recovered (kWh/kg-COD)	Power Generated (kWh/d)	CO2 Emissions related to electricity consumption (ton-CO2e/yr)	CO2 Emissions related to biological activity (ton-CO2/yr)	CH4 Emissions related to biological activity (ton-CH4/yr)
Aerobic	8,123	5,077	0.7 - 1.0	5,686 - 8,123	NA	NA	678 - 968	1.69E-03	1.49E-04
Anaerobic	8,123	5,077	0.4 - 0.7	3,249 - 5,686	1.0 - 1.2	8,123 - 9,747	387 - 678	1.65E-03	6.50E-04
BETT	8,123	5,077	0.1 - 0.2	812 - 1,625	1.1 - 1.6	8,935 - 12,996	97 - 194	1.39E-03	1.25E-08

It should also be noted that neither activated sludge or anaerobic digestion could directly treat a waste stream with a starting COD concentration of 100,000 mg/L. Activated sludge processes require a 250x dilution factor for adequate treatment in a reasonable footprint (< 43,000 sq-ft). Anaerobic digestion processes require a 5x dilution factor for adequate treatment in a reasonable footprint (< 43,000 sq-ft). BETT can treat the waste concentration and flows directly, without dilution, in a footprint equivalent to 4x 40-ft by 8-ft shipping containers (1000 sq-ft with service area). Containers can also be stacked to save space.

Calculations for aerobic and anaerobic treatment technologies were calculated using standard methods[1]. Calculations for BETT are based on pilot demonstrations operated at commercial sites treating similar wastewater concentrations. BETT efficiencies for COD removal and energy recovery do not change with scale. In fact, BETT efficiencies are additive as the systems scale. Therefore, the demonstration data provide adequate results for estimating technology capacity at scale.

[1] Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal Wastewater Treatment Ethanol Fermentation. U.S. Environmental Protection Agency Sector Policies and Programs Division Measurement Policy Group. Author: RTI International (2010). https://www3.epa.gov/ttnchie1/efpac/ghg/GHG_Biogenic_Report_draft_Dec1410.pdf