Municipal 12 Month Pilot: Energy and Treatment Results

Overview:

MICROrganic Technologies is developing Bio-Electrochemical systems for energy-positive secondary wastewater Treatment. Aeration is the most energy-intensive process wastewater treatment, averaging 57% of a plant's energy-budget (15% - 20% of OpEx.) Energy expenses vary significantly by:

- plant size
- equipment age & type
- waste strength
- local utility power costs
- energy-recovery technologies in place
- demand power costs
- power outage mitigation

MICROrganic installed a Secondary Wastewater Treatment pilot in February 2019 at the Pittsfield WWTP. The plant is rated to treat up to 15M GPD; typical effluent flow is 12M GPD. The pilot treats ~10,000 gallons (38 Cubic Meters) of wastewater daily and has run continuously since it became operational.

Pllot Description and Results

The VIVA Pilot installation comprises two 2500 Gallon tanks, each filled to approximately 2300 Gal/tank. Only one of the tanks have VIVA Electrodes; the second tank circulates additional effluent that allows the pilot to treat a total of 10k Gal/Day.

Influent from the plant's Primary Clarifier Outfall (pre-secondary) circulates through the VIVA™ reactor for BOD reduction. The treated waste effluent returns to the Primary Clarifier. Influent strength is about 120 mg/L BOD (low-typical range for a municipality). The US EPA BOD discharge requirement is < 30 mg/L. Typical plant effluent discharge is 15 mg/L. The plant also has a nitrogen mandate.

The Pilot reactor consistently reaches treatment rates comparable to plant performance: overall pilot effluent ranged from 5 mg/L to 30 mg/L, most commonly around 12 mg/L. Based on data from >12 months of operation, MICROrganic is developing protocols to test increasing influent circulation up to 40,000 gal/day.

Standard Plant Typical Range of Energy Metrics

Typical WWT Energy Use	**Annual MWh**	**Comments**
Low end plant energy-use at 12 MGD-	4,974	@ .3kwh/cubic meter
High end plant energy-use at 12 MGD	9,947	@ .6kwh/cubic meter
Low end aeration at 57% of total energy	2,487	@ .3kwh/cubic meter

High end at 57% of total energy	5,670	@ .6kwh/cubic meter
NYSERDA/Avg. Aeration intensive w/ nitrification (applicable to Pittsfield)	3,942	NYSERDA study
NYSERDA/Avg. Energy use, Trickling Filter	460	@ 2 million gallons
NYSERDA avg. energy/fine bubble aeration	5,840 - 10,950	1600 - 3000 kwh/MG

The City of Pittsfield upgraded Aeration equipment within the last decade replacing their energy-intensive, aging aeration system with a newer energy-efficient system (Fine Bubble Aeration), as well as three high-efficiency blowers. Fine Bubble technology launched in the 1970s, as an energy-efficient alternative to mechanical aerators and coarse bubble aeration. Today, Fine Bubble Aeration is extensively deployed for both Industrial and Municipal waste. It is much more energy-efficient because smaller bubbles (around 2 mm in diameter) stay in the water longer than larger bubbles.

Pittsfield Aeration Equipment:

- Pittsfield has three energy-efficient blowers that were installed when they added Fine Bubble Aeration. Each blower has a capacity of 150kw, but are tuned to 120kw.
- The blowers run 24/7, in series (for redundancy); one at a time
- Typical flow is 12 MG/Day; with adverse weather, flow can increase up to 15M (plant capacity)

Wastewater Treatment Metrics: General and Pittsfield Specific

General WWT Efficiency Data:

- Average US WWT energy use is .3 - .6 kWh per cubic meter of Wastewater (264 gal Municipal)
- Average aeration treatment for a plant of Pittsfield's size ranges from 17 - 34 kWh/Day or 6,200 - 12,400 MWh annually.
- Pittsfield average treatment rate: 12M Gal/Day (45,425 Cubic Meters/Day)
- **Pittsfield's Fine bubble Aeration Usage is 8640 kWh/day, or approx. 3153 MWh annually**
- Pittsfield also deploys a trickling filter system that requires a 100 hp pump, with equivalent power use of 74kw. **Energy use from the Trickling Filter represents approx. 650 MWh annually.**
- Pittsfield's total annual Aeration energy use (Trickling Filter and Fine Bubble) is approx. 3700 MWh.
- High flow requires a second pump for the trickling filter - both are deployed above 12MGD (< 10% of days). Deploying the second pump requires about 1800 kW. We do not have a record of deployment of the second pump.
- **Assuming 20 days with higher flow, additional energy use would be 72 MWh.**
- **Average Annual Aeration Energy Use Total: 3872 MWh.**
- **Other costs:** power outages (infrequent) create significant additional energy charges at the plant. They must deploy generators to maintain aeration and pumping. Estimated $10K per episode (restarting all the equipment causes a very large power load), plus the cost of running the generators and assuming that 50% of those costs are related to aeration, yield additional expense. 3 Power Outages would add another $30K electricity expense.
- Pittsfield pays $.08685 per kWh. Total annual energy costs for aeration (excluding demand charges) are about $150,000. (This estimate does not include power required by the second pump for the Trickling Filter, or additional costs associated with power outages.)

Power Generation:

Currently, VIVA MFC generates approx. 1W per SM of Cathode material. This 10K Gal/Day Pilot deployed 10 SM of cathode, generating approx. **240 Wh** daily. On an annual basis, power generation from the pilot totals 88 KWh.

A scaled extrapolation suggests that power generation at a plant the size of Pittsfield could generate from 50-100 mWh annually. Note: the power generation range is large because we have not established electrode requirements for larger-scale systems; it is possible that much larger systems might require fewer electrodes, which would limit generation. That said, we do not see that possibility as a negative; in fact, a more lean electrode profile requirement would be even more economical from a cost standpoint and would not jeopardize energy efficiency.

Energy Cost Data Snapshot:

June 2019: Total plant Power Cost: $56,741
Utility Energy charge: $36,616
Utility Supply charge: $20,125

Pittsfield Aeration Power Draw: 89,280 kWh (Blowers)
55,056 kWh (Trickling Filter)
Monthly Power Sub-total: 144,336 kWh
Annual Power Total: 1,732,023 kWh (1732 mWh)

Pittsfield Aeration as Percentage of total plant energy use in June: 34% (Note, this percentage is lower than the US average; on average, Aeration is responsible for 57% of a plant's total energy usage.

Pittsfield Plant GHG Equivalency for current system:

- 1,253 Metric Tons of CO2
- 3,063,745 miles driven by an average passenger vehicle

Comparison of Pittsfield Data, Pilot Data and "Typical" Plant Energy Use

The Pittsfield WWTP is more energy and cost-efficient than the US average; their Secondary Treatment energy-use is 17% more efficient than an "average" plant (.3kwh/m3), and about 25% lower than plants with energy usage at higher energy-intensity (.6kwh/m3)

If VIVA MFC were to be deployed at Pittsfield (or a comparable plant), we anticipate Aeration power requirements would be less than 160 MWh - reducing their "aeration" costs by 85% (vs. the current Fine Bubble energy use of 1050 MWh annually). Note: installation of VIVA MFC would not impact power use with the trickling filter. Trickling Filters cannot be easily retrofitted to VIVA MFC. That said, there are two potentially beneficial outcomes that we could envision, regarding the Trickling Filter:

1. The Fine Bubble system could be de-installed and retrofitted with VIVA MFC
2. A plant such as Pittsfield could turn off the Trickling Filter, and potentially use the Aeration Bay space to add more VIVA MFC treatment capacity, for additional energy efficiency. This suggestion is a consideration; we do not have enough information to make a recommendation.

Average Range of Aeration Costs: Conventional and Pittsfield-Specific
2,479,245 KWH - @ .3kwh/m3
4,958,490 KWH - @ .6kwh/m3
Actual Pittsfield energy-use: .1025 kwh/m3

Conclusions and Summary:

The Pittsfield plant has many assets: experienced Operators, multiple lab staff, modern equipment, and judicious management, resulting in a well-functioning, energy-efficient plant. Due to significant energy-efficiency and the relatively "young" aeration system, plant's like Pittsfield are not likely to upgrade to VIVA MFC unless they face other significant issues. Smaller plants (< 2 MGD, comprising over 70% of US WWT Plants) often lack the depth and breadth of expertise that larger plants can summon, represent a significant proportion of plants using older, less energy-efficient Aeration technologies. These smaller plants would benefit significantly from both significant energy savings and intelligent process monitoring available with VIVA MFC.

One other aspect that was not a part of this pilot is the issue of Nitrogen remediation. Nitrogen is a pervasive pollutant that can significantly damage natural waterways. Remediation of nitrogen in WWT is expensive, more energy-intensive than biological treatment (typically 4x), and as critical as secondary treatment in preserving our natural bodies of water. Many plants, including Pittsfield, are under mandates to achieve specific Nitrogen reductions, to maintain their operating permit. Pittsfield's mandate is to manage nitrogen discharge through the step of Nitrification (an aerobic process that begins degradation of ammonia). The full process of nitrogen removal is more energy-intensive than aeration. VIVA MFC provides an anoxic zone (the bulk wastewater fluid) and an aerated zone (the surface of the cathode).

MICROrganic is working with a company that is developing a Nitrogen sensor; we are testing their sensor, along with standard N lab testing, to evaluate the sensor's accuracy and commercial utility, compared to the expensive, time-consuming methods that are universally deployed currently. Successful nitrification and denitrification using VIVA MFC can be an additional, compelling reason to adopt VIVA MFC. Nitrogen removal by current methods is 4X more energy-intensive than Aeration, per pound of N. Our early results indicate that VIVA MFC reduces nitrogen 35% - 50%

Early Adopter Primary Targets:

- Small Food & Beverage manufacturers that are being "pressed" by municipalities that don't have the capacity to accept large volumes of high-strength waste, to provide significant Pre-Treatment to lessen the burden on the municipality.

- Small Municipal Plants (up to 2M Gal/Day) with aging equipment, and potentially struggling with the resources to run the plant given increasing mandates and concerns about water safety and sustainability.

The Pittsfield pilot, although not concluded, has provided many benefits to our product development and understanding of customer value. Aggregate Pilot data will allow us to size and more accurately price systems, while offering customers the highest possible energy-efficiency. In addition, two key attributes of VIVA MFC enhance the value of the system: continuous DC power generation and real-time treatment data and system notifications that will provide operators with more control over their process, more data on

system performance, and additional costs mitigation due to DC power generation. We are currently in discussion with UMass Amherst to explore pilot opportunities for intelligent software development to further enhance WWT system intelligence. (UMass Amherst has a WWT system on-site, and robust technical skills in WWT.)