Executive Summary: Draft PA No. 5 – Improved Digester Mixing System at Santa Cruz WWTP

Description

An improved digester mixing system at the City of Santa Cruz Wastewater Treatment Plant (WWTP) would include replacing the existing gas mixing system with a more energy efficient pump mixing system to save energy and reduce indirect GHG emissions.

Amount of GHG Reduction

The energy savings from the improved mixing system would correspond to an annual GHG reduction of approximately 266 MT CO_2e and total of 5,324 MT CO_2e over the project life. This project could reduce approximately 40 to 60% of the potential GHG reduction goals for SCWD, and 15 to 20% of the potential GHG reduction goals for SqCWD.

Project Life and Sustainability

An improved digester mixing system would continue to provide energy savings and GHG reduction for the 20 year life of the project. The project would be sustained by normal maintenance and repair.

Project Cost

This project would result in an overall benefit to SCWD over the project life. The average annual net cost of the project is approximately -$19,000 per year, because the savings from reduced energy use is greater than the cost to install and run the project. Since the project results in a net benefit, the project lifecycle GHG reduction cost per metric ton (approximately -$45 per MT CO_2e) also provides a net benefit to SCWD.

Table ES-1: Improved Digester Mixing System Project Summary

Project Life (yr)	Annual GHG Reduction (MT CO_2e/yr)	Capital Cost ($ million)	Average Annual Net Cost ($/Yr)	Lifecycle Energy Cost ($/kWh)	Lifecycle GHG Reduction Cost ($/MT)	Space Required
20	266	$1.4	-$19,000	-$0.01	-$45	None (replacing existing equipment)

Draft Project Assessment No. 5 – Improved Digester Mixing System at Santa Cruz WWTP

Description

This assessment estimates the energy savings and GHG reduction potential from upgrading the existing digester mixing system at the City of Santa Cruz (City) Wastewater Treatment Plant (WWTP).

Background

The WWTP meets solids stabilization requirements by using three primary digesters with a combined active volume of 4.5 million gallons. The sludge in the primary digesters is mixed with a gas mixing system, which is comprised of ductile iron piping, two 60-horsepower (HP) compressors per digester, and associated valves, electrical equipment and controls. The compressors operate 24 hours per day, 365 days per year. Mixing is required in order to adequately expose the microbial culture in the digesters to the sludge, which is their food source.

In a gas mixing system, digester gas is pumped into the bottom of the digester. Mixing comes from the combination of the released gas, the rising bubbles, and reduced sludge density. However, with gas mixing systems, the bottom portion of the digester often is not adequately mixed, and any grit that would normally be in suspension will tend to accumulate on the bottom and become problematic. Also, the mixing tends to be uneven – intense in localized areas and sporadic in others. In addition, gas systems have limited capacity; the mixing ends when the gas bubbles reach the liquid surface. Sufficient mixing of the entire tank volume is needed to prevent the accumulation of grit on the floor and to minimize the creation of a scum blanket on the surface. The level of digester mixing depends on the method of mixing that is used.

Externally pumped mixing systems are characterized by highly uniform mixing. The high velocities that are developed at the discharge nozzles create a swirling motion, or spiral vortex that continues throughout the digester. A considerable amount of “shear,” or breaking up, is experienced by the solids in an externally pumped mixing system. This shearing action reduces the size of the solids particles and subsequently increases the surface area exposed to the microbial culture in the digesters, resulting in higher volatile solids destruction and increased digester gas production. Pump mixing systems tend to require less input energy than systems that rely on compressed digester gas for mixing. Pumps mixing systems also reduce grit build-up in the bottom of a digester and mat formation at the surface, thereby extending the time period between expensive cleaning cycles for the digester.

Changing from a gas mixing to an externally pumped mixing system can also potentially increase the performance of a digester in terms of volatile solids (VS) destruction. Additional VS destruction results in an increased production of digester gas. Historical data for the WWTP suggests the primary digesters have experienced VS destruction in the range of 55 to 60%. It is anticipated that this destruction rate could increase to 60 to 65% with inclusion of an externally pumped mixing system.

Figure 1: Typical Externally Pumped Digester Mixing System

The San Francisco State University School of Engineering (with support from the U.S. Department of Energy) completed an Energy Conservation and Waste Management Report in December 2010 for the City (SFSU Report). This report made a recommendation to replace the existing gas digester mixing systems with externally pumped digester mixing systems at the City WWTP. In addition, the SFSU Report also recommends replacing the existing gas compressors that are dedicated to each primary digester with one 25 HP centrifugal pump for the pump mixing system.

Kennedy/Jenks was asked by the City to evaluate the findings of the SFSU Report prior to doing this assessment. After reviewing the calculations, assumptions, and estimated energy savings presented in the SFSU Report, it was determined that the amount of savings and estimated payback period were overstated.

Based on the active digester volumes provided by City staff, and assuming a total dynamic system head of 14 feet and typical efficiencies, a single 25 HP centrifugal pump for each digester would provide a flow rate of approximately 3,900 gallons per minute (gpm). Digester mixing energy and distribution is typically measured in terms of turnovers of digester contents per day (pumping of the entire volume is one turnover). A 3,900 gpm pump would provide approximately 4.6 turnovers per day for Digester 1 (smaller digester), and 3.5 turnovers per day if used at each of Digesters 4 and 5 (larger digesters). The recognized industry guideline is between 8 and 12 turnovers per day of the tank contents in order to adequately expose the microbial culture to the available food source and distribute thermal energy from the sludge heating system. In order to provide the recommended mixing, a single 50 HP centrifugal pump should be used for each digester, rather than 25 HP (as recommended in the SFSU Report). The corresponding mixing distribution for the two different pump sizes is presented in Table 1.

Table 1: Digester Mixing Distribution Comparison

Digester No.	Active Digester Volume (gal)	SFSU Report	K/J Analysis
		Digester Mixing (turnovers/day)	Digester Mixing (turnovers/day)
		25 HP Pump	50 HP Pump
Digester 1	1,204,000	4.6	11.3
Digester 4	1,596,000	3.5	8.5
Digester 5	1,596,000	3.5	8.5

The SFSU Report also includes an assumption that the new pump will only operate for 12 hours per day. Empirical data from similar sized facilities operating with externally pumped mixing systems has shown that, in order to transfer sufficient mixing from the pump to the contents of the digester, the pump must operate continuously. Mixing systems that have insufficient mixing can suffer from dead spots that reduce the volatile solids destruction and therefore reduce digester gas production.

Vendors

The mixing pumps can be either a chopper style centrifugal pump that produces mechanical shearing as the sludge passes through, or a screw style centrifugal pump that produces hydraulic shearing at the discharge nozzles with a non-clog volute and impeller configuration. Screw centrifugal pumps are characterized by a pumping efficiency approximately 25% higher than chopper pumps and therefore are recommended for Santa Cruz. Hayward Gordon and Wemco have been manufacturing the appropriate screw centrifugal pumps for more than 15 years.

History and Technical Maturity

Gas mixing systems were the preferred technology at wastewater treatment plants starting in the 1960s. However, over the last 20 years, municipalities have found that gas mixing systems are ineffective at distributing the mixing energy throughout digester tanks, resulting in “dead spots” and reduced rates of volatile solids destruction, and therefore create lower digester gas production. In the San Francisco Bay Area, the North San Mateo County Sanitation District, San Leandro WPCP, Millbrae WPCF, and Central Marin Sanitation Agency have all either replaced, or are in the process of replacing, their gas mixing systems with new externally pumped mixing systems. Both gas and pump mixing systems are well developed and technically mature.

Reliability and Operational Complexity

Externally pumped mixing systems are comprised of pumps, piping, minor instrumentation, and electrical equipment (motor control centers, conduit, and wires). These types of mixing systems have been proven to be extremely reliable throughout the United States, and are now being recommended for any plant looking at potentially accepting fats, oils, and grease (FOG), or food waste (FW).

Major benefits of an improved mixing system are energy savings, better volatile solids destruction, elimination of high pressure gas piping and its inherent hazards, and increased digester gas production.

A potential downside to replacement of the existing gas mixing system is the risk associated with coring large diameter holes in the sidewalls of the digesters for the mixing piping, and the possibility of additional cost associated with strengthening the existing wall.

The retrofit project is not anticipated to have any adverse impacts on City operations. The City staff is accustomed to operating and maintaining centrifugal pumps and the instrumentation associated with this type of project. The system runs continuously, so monitoring of speed, flow rate, or other parameters is not required. The City may actually see a reduction in maintenance requirements for the centrifugal pumps compared to gas compressors, because the pump systems tend to be more reliable.

Sustainability

Improving the mixing system at the City WWTP would continue to provide energy savings for the life of the project. The project would be sustained by normal maintenance and repair.

Local Considerations

Improving the digester mixing system at the Santa Cruz WWTP will benefit the local community by reducing the amount of energy used to digest sewage sludge and potentially increasing the total gas production through enhanced VS destruction.

Economy

Construction of the improvements would require approximately 4 to 5 months of downtime per digester, but the required labor could come from the local community.

Environment

Air: Centrifugal pumps do not have any direct emissions.

Land: Since this project involves replacing existing unit without any increase in the digester footprint there is no significant impact on land.

Water: Centrifugal pumps without mechanical seals do not consume water or create any water pollution.

Noise: Centrifugal pumps are generally quieter than air compressors, potentially resulting in a reduction in overall noise from the WWTP.

Aesthetic/Visual: The pumps would be placed at grade, with some large diameter piping extending from the digester walls. The aesthetic nature of the piping and equipment would be similar to other equipment at the plant, and not visible from outside the property.

Waste by-product: Some pumps utilize grease for bearings and oil for the mechanical seal, and would need to be disposed of properly.

Energy Savings and GHG Reductions

Digester mixing is a continuous process, so energy savings would result from operation of the digester mixing pumps on a full-time basis. Energy savings included in the SFSU report were based on operating all three primary digesters simultaneously, although with the compressors operating at a utility factor of 0.64, or essentially two-thirds of the time. This is equivalent to the gas systems for two of the digesters operating full-time. Current practice involves having one digester out of service at any given time, so full-time operation of gas compressors for two of the digesters is a more realistic scenario. The energy savings estimated below are based on operating digester mixing pumps for the two primary digesters (Digesters Nos. 4 and 5) 100% of the time.

The energy usage associated with operating the existing gas mixing systems for two digesters is approximately 1,568,400 kWh per year. This accounts for roughly 14% of the total energy demand for the plant (based on 11,626 MWh per year). As shown in Table 2, by replacing the existing gas mixing system with a pump mixing system in Digesters 4 and 5, the estimated energy savings is approximately 915,000 kilowatt hours per year (kWh/yr), or a savings of nearly 60%.

Table 2: Mixing Systems Comparative Energy Use

Scenario	Equipment	Motor Size (HP)[1]	# of Units	Duty Factor[2]	Annual Electricity Usage (kWh)	Peak Electrical Demand (kW)
Existing	Digester 4 Gas Compressors	60	2	100%	784,200	90
	Digester 5 Gas Compressors	60	2	100%	784,200	90
				Total Existing	**1,568,400**	**179**
Future	Digester 4 Mixing Pump	50	1	100%	326,700	37
	Digester 5 Mixing Pump	50	1	100%	326,700	37
				Total Future	**653,400**	**75**
				Total Energy Savings	**915,000**	**104**

[1] Assumes similar efficiencies for both types of equipment.
[2] Percent of time in operation.

Included in Table 3 is the potential estimated GHG reduction for implementing the project.

Table 3: Energy Savings and GHG Reductions for an Improved Mixing System

Annual Energy Savings (kWh/year)	Annual GHG Reduction (MT CO_2e/year)
915,000	266

This project could reduce approximately 40 to 60% of the potential GHG reduction goals for SCWD, and 15 to 20% of the potential GHG reduction goals for SqCWD.

Cost

The capital costs shown in Table 4 are based on installation of non-clog centrifugal mixing pumps, large diameter welded steel piping, and associated electrical equipment and instrumentation. This assessment is based on upgrading only the two larger digesters to the externally pumped mixing system; leaving the smaller digester with the existing gas mixing system. Retrofitting the smaller digester does not result in significant energy savings, would not significantly impact reliability of the system, but would increase the capital costs for the project.

The capital cost to improve the mixing system on two of the WWTP's three digesters is estimated at $1,500,000. There is a one-time rebate incentive from PG&E through their Customized Retrofit Incentive program in the amount of $0.09/kWh for the first year's savings, resulting in a capital cost savings of $100,000. Operation and maintenance costs (with the exception of energy cost) are similar to that of a gas mixing system, and would require approximately 0.1 full time equivalents (FTE). With proper maintenance, a pumped system should last approximately 20 years. This project's benefits (from electricity savings) exceed its costs (from the capital cost and O&M) resulting in a negative net cost, or a benefit to SCWD.

Table 4: Estimated Improved Mixing Project Costs

Project Life (yr)	Capital Cost ($ million)	Average Annual Net Cost ($/Yr)	Lifecycle Energy Cost ($/kWh)	Lifecycle GHG Reduction Cost ($/MT CO_2e)
20	$1.4	-$19,000	-$0.01	-$45

Summary of Advantages and Disadvantages

Advantages:

- Overall financial net benefit to SCWD.
- Energy savings from a reduction in total needed horsepower for operations.
- GHG reduction from associated energy savings.
- Better mixing resulting in more volatile solids destruction, a reduction in "dead spots," and an increase in digester gas production.
- Ability to accept fats, oils, grease, and food waste for potential waste-to-energy project that could further provide environmental benefits.
- Project is located in the local community.

Disadvantages:

- Risk and cost associated with the required drilling of large holes in the digester walls.

References

San Francisco State University School of Engineering. Energy Conservation and Waste Management Report. December 2010.