*Wastewater Treatment and Waste-to-Energy Solutions*

ADI SYSTEMS

# Anaerobic Membrane Bioreactor (ADI-AnMBR) Treatment Solutions for Food Processing Wastewater

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## Introduction

ADI Systems' anaerobic membrane bioreactor (ADI-AnMBR) process incorporates anaerobic digestion and membrane filtration in one process. Adding membrane filtration within an anaerobic system offers the advantage of complete biomass retention in the reactor, leading to a very stable process while generating lower quantities of waste sludge, and producing an extremely high-quality anaerobic effluent with virtually negligible effluent suspended solids. The AnMBR process described in the following case studies utilize flat-sheet membrane cartridges (with nominal pore size of 0.2 micron) that are submerged directly in the anaerobic biomass, completely blocking all suspended solids (SS) from escaping to the effluent. Figure 1 presents a general process flow diagram of the AnMBR process.

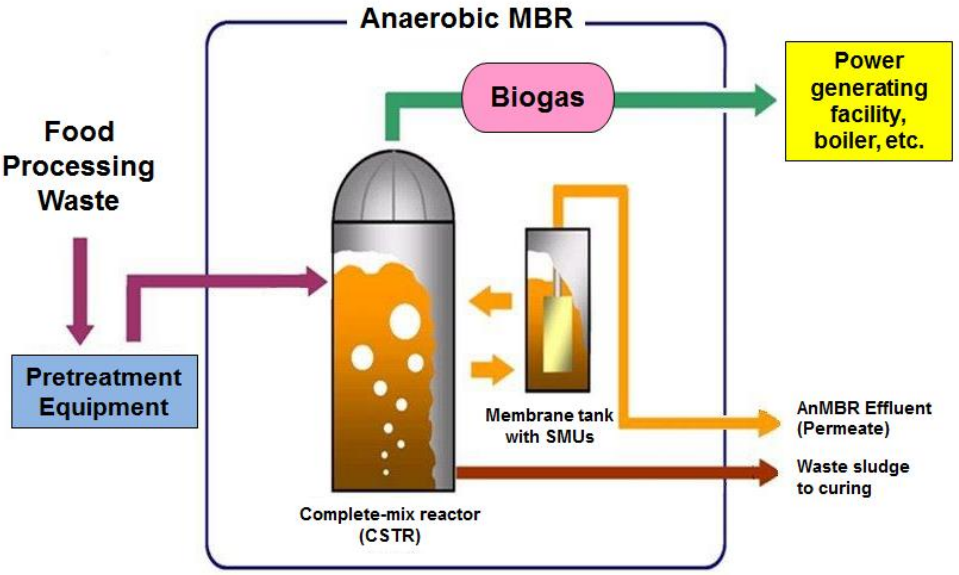


*Figure 1: General process flow diagram of the AnMBR process*

## The Process

The AnMBR is a unique form of anaerobic digestion with superior effluent quality which is ideal for the development of renewable energy from waste, especially for treatment of biodegradable industrial wastewaters with high organic strength, high SS, and some fat, oils, and grease (FOG).

The flat-sheet membranes are submerged directly into the membrane tank. A recirculation loop between the membrane tank and complete-mix digester ensures a constant mixed liquor concentration in the membrane tank. The permeate is withdrawn from the mixed liquor through the membrane.

The biogas generated from the anaerobic process can be sent to a flare or utilized in a boiler or to produce electrical power. Biogas is recirculated from the head space of the membrane tank and forced through a coarse bubble diffuser located beneath the membranes to scour the membrane surface. This scouring significantly reduces the membrane fouling rate while mixing the membrane tank contents.

The AnMBR process provides numerous process advantages over conventional anaerobic treatment processes including:

1. A superior quality anaerobic effluent is produced on a consistent basis. Typically, AnMBR effluent quality is sufficient to significantly reduce and sometimes even completely avoid aerobic post-treatment when discharged to a local publicly owned treatment works (POTW).

2. High organic loading rates (6-15 kgCOD/$m^3$d) are achievable, minimizing the reactor size and footprint of the treatment plant.

3. Total suspended solids (TSS) removal is typically not required ahead of the AnMBR. In some cases, FOG removal is not required allowing TSS and FOG to be digested which simplifies the overall system, eliminates primary treatment equipment, increases biogas yield, and further reduces waste sludge production, handling, disposal, and associated costs.

4. Waste activated sludge (WAS) from a downstream aerobic process (if present) can be digested in the AnMBR system. This again simplifies the overall process, increasing biogas yield, and reducing overall waste sludge handling/disposal costs.

5. Complete retention of the biomass by the membranes assures a consistently high degree of treatment with negligible effluent TSS concentrations and superior process stability.

6. The complete retention of biomass allows the solids retention time (SRT) and hydraulic retention time (HRT) to be controlled independently.

7. Granular seed sludge is not required, eliminating costs associated with obtaining granular seed sludge and maintaining this type of special sludge in the system.

The AnMBR process with Kubota membranes was developed and tested in the mid-1990s and systems have been in full-scale operation since 2000. AnMBR technology remains an active area of research within wastewater treatment.

This paper presents three full-scale systems treating food processing wastewater:

- Ken's Foods in Marlborough, Massachusetts, USA
- A confectionery manufacturer in south central Pennsylvania, USA
- Kellogg Company Pikeville Plant in Kimper, Kentucky, USA

# Ken's Foods

## Introduction

Ken's Foods is a leading producer of salad dressing and barbeque sauces located in Marlborough, Massachusetts, USA. In 2008, Ken's Foods' existing wastewater treatment system was in need of upgrading in order to treat an additional 60 percent flow and load increase beyond the existing treatment plant's design capacity. Lack of space, superior economics, and treatment performance made converting the existing anaerobic process to an AnMBR an attractive option.

The AnMBR utilizes a 8,300 $m^3$ (2.2 MG) circular concrete lead reactor and four membrane tanks fitted with submerged membrane units, each with a working volume of 100 $m^3$ (27,000 gal).

## Full-Scale Operating Results

The AnMBR was commissioned in 2008 and is operated at mesophilic temperature conditions. The system temperature is controlled through a spiral heat exchanger, with heat supplied by a biogas-fuelled boiler. The continuous recycle of biomass between the circular lead reactor and the membrane tanks also provides the means of maintaining consistent mixed liquor suspended solids (MLSS) concentration throughout the AnMBR system. The average pH in the AnMBR is maintained well at 6.9±0.1 for anaerobic sludge conditions.

*Figure 2: Ken's Foods' AnMBR system (membrane tanks)*

Table 1 presents the average raw wastewater characteristics and effluent quality of the past eight years.

Table 1: Operating Data from Ken's Foods' AnMBR system

| Parameter | Influent | Effluent | Removal |
|---|---|---|---|
| **Flow ($m^3/d$)** | 380 (100,000 gpd) | 380 (100,000 gpd) | - |
| **COD (mg/l)** | 37,400 | 250 | 99.3% |
| **BOD (mg/l)** | 18,000 | 25 | 99.9% |
| **TSS (mg/l)** | 11,500 | <3 | ~100% |
| **FOG (mg/l)** | 840 | nil | ~100% |

The AnMBR was designed to treat 475 $m^3/d$ (125,000 gpd) of raw wastewater with characteristics of 39,000 mg/l COD, 18,000 mg/l BOD, and 12,000 mg/l TSS. Figures 3 and 4 present the AnMBR system influent and effluent COD and TSS concentrations from the AnMBR system.

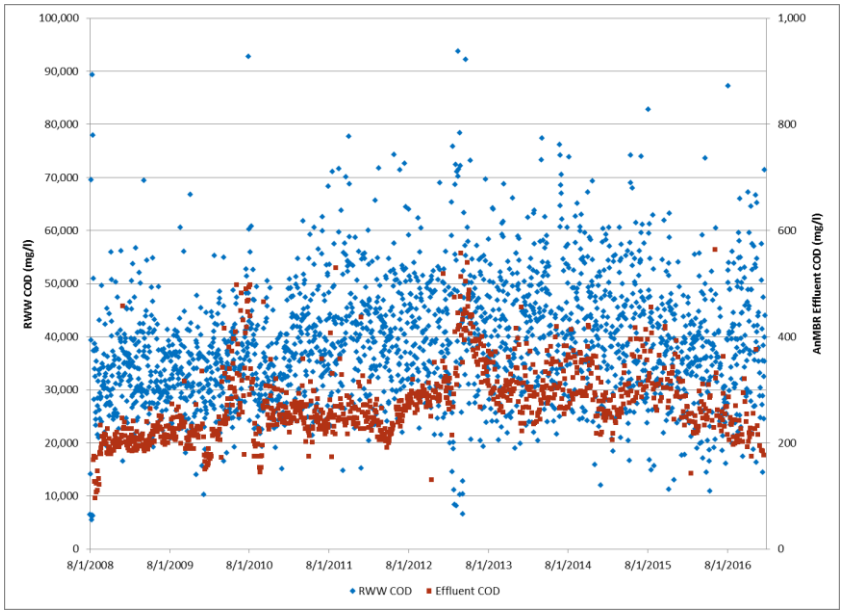


*Figure 3: Influent and effluent COD concentrations for the AnMBR system at Ken's Foods*

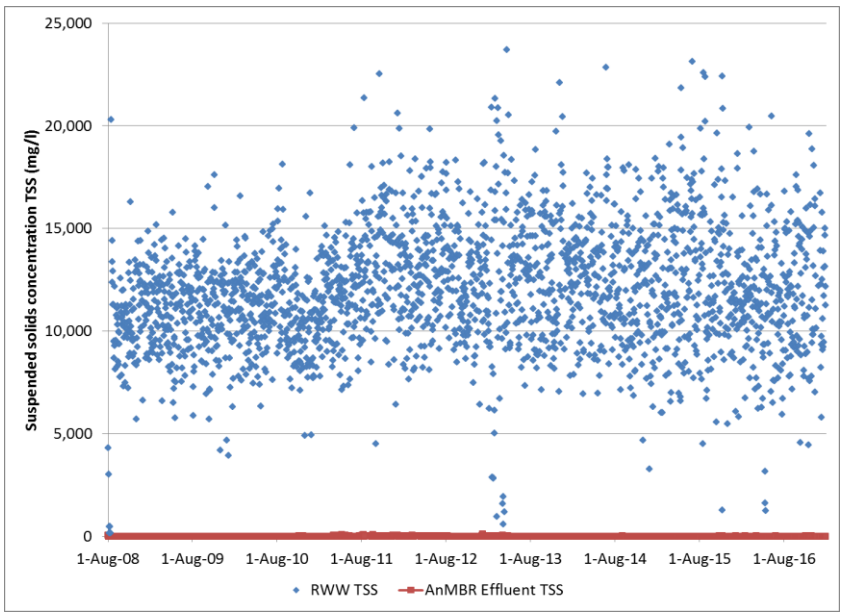


*Figure 4: Influent and effluent TSS concentrations for the AnMBR system at Ken's Foods*

The AnMBR at Ken's Foods produces a very high-quality effluent with COD removals of 99.3 percent and TSS removal of nearly 100 percent. The system also provides complete digestion of the raw wastewater FOG, providing further biogas and better production while avoiding up-front FOG removal. There have been no signs of FOG accumulation or FOG associated problems after eight years of operating the system.

Since the AnMBR effluent contains virtually no solids, a waste sludge metering pump with piping connecting the membrane tanks to the final effluent discharge point allows Ken's Foods to discharge anaerobic solids to the sewer while still meeting the POTW TSS discharge limit of less than 230 kg/d (500 lb/d). Ken's Foods only operates the centrifuge intermittently for sludge dewatering and wasting. Dewatered sludge cake solids typically average 17-18 percent. Sludge yield for the AnMBR is 3 percent based on COD removed (this yield includes the sludge wasted to the sewer).

Membrane cleanings are required when the transmembrane pressure (TMP) reaches 10 kPa (40 inches of water column). The membranes in each basin are cleaned in-situ on a cleaning schedule to ensure that the operating flux remains at the design flux. Typically, cleanings are done once every three months. To date there has been no evidence of any decline in membrane permeability and no membrane cartridges have been replaced after over eight years of operation.

### Conclusion

The AnMBR at Ken's Foods successfully treats the processing wastewater from the salad dressing and BBQ sauce production plant. The process operates effectively in treating the wastewater removing greater than 99 percent of the influent COD, BOD, TSS, and FOG.

Converting the existing anaerobic treatment system to an AnMBR demonstrated the simplicity and suitability of AnMBR technology for upgrading existing systems. This allows treatment of higher flows and organic loads while achieving a higher quality effluent and significantly reduced operating costs and operator attention. After eight years of operation, there have been no issues regarding the permeability and durability of the flat-sheet, submerged membranes, nor any issues with the cassettes or diffusers.

More recently, Ken's Foods has chosen to install an AnMBR at its plant in McDonough, Georgia, USA. The system will be integrated with the plant's existing aerobic system to meet required discharge limits. The technology will combine the anaerobic digestion and membrane filtration into one simple process, making it compact and therefore suitable for the space limitations at the plant. This project is a testament to the reliable wastewater treatment that can be achieved with this type of technology.

## Confectionery Manufacturing Plant

### Introduction

The confectionery manufacturing plant discussed in this paper is located in south central Pennsylvania, USA. The facility had an existing anaerobic system which consisted of an EQ tank, three hybrid (fixed-film) anaerobic reactors, a degas tower, and a clarifier. With a new production line coming online and additional hydraulic capacity required, the existing treatment

system at the confectionery manufacturing plant was in need of an upgrade. With stricter discharge limits coming into effect, the existing system would not have been capable of treating the process wastewater while consistently meeting the effluent limits.

The existing treatment system at the plant was modified to an AnMBR system by converting one of the existing hybrid reactors to a continuous stirred tank reactor (CSTR) and adding two membrane tanks with continual sludge recycle back to the CSTR. The configuration to an AnMBR has provided treatment for the process wastewater and the additional co-product waste (which was being hauled off-site). The incorporation of the AnMBR treatment process eliminated the need for two of the existing hybrid reactors, the degas tower, and the clarifier. This simplified the overall anaerobic treatment process while treating more wastewater flow, significantly higher organic load, and consistently producing a significantly better quality effluent that is discharged to the local POTW.

The AnMBR utilizes the existing 500 $m^3$ (130,000 gal) hybrid reactor (converted to a CSTR) and two membrane tanks (each with a volume of 160 $m^3$ (43,000 gal)) fitted with submerged membrane units. The hybrid media was removed from the existing tanks, as it was severely plugged after several years of operation. Side entry mixers were added to the existing hybrid tank to effectively convert it to a CSTR as part of the upgraded AnMBR process.

## Full-Scale Operating Results

The AnMBR was commissioned in 2012 and is operated at mesophilic temperature conditions. The system temperature is controlled through existing spiral heat exchangers, with heat supplied by a biogas-fuelled boiler. The continuous recycle of biomass between the CSTR and AnMBR tanks provides a means of maintaining the temperature at 35°C (95°F). The average pH in the AnMBR is maintained well at 7.1±0.1 for anaerobic sludge conditions.

*Figure 5: Membrane tanks of the AnMBR system at the confectionery manufacturing plant*

Table 2 presents the AnMBR system average raw wastewater characteristics and effluent quality over 12 months of operation.

Table 2: Confectionary manufacturing plant's AnMBR actual operating data

| Parameter | Influent | Effluent | Removal |
|---|---|---|---|
| **Flow ($m^3$/d)** | 155 (41,000 gpd) | 155 (41,000 gpd) | - |
| **COD (mg/l)** | 12,000 | 350 | >97% |
| **BOD (mg/l)** | 4,400 | 30 | >97% |
| **TSS (mg/l)** | 1,200 | nil | ~100% |

The AnMBR was designed to treat 170 $m^3$/d (45,000 gpd) of raw wastewater with characteristics of 16,600 mg/l COD, 8,000 mg/l BOD, and 10,000 mg/l TSS. Figure 6, 7, and 8 present the influent and effluent COD, BOD, and TSS concentrations from the AnMBR system.

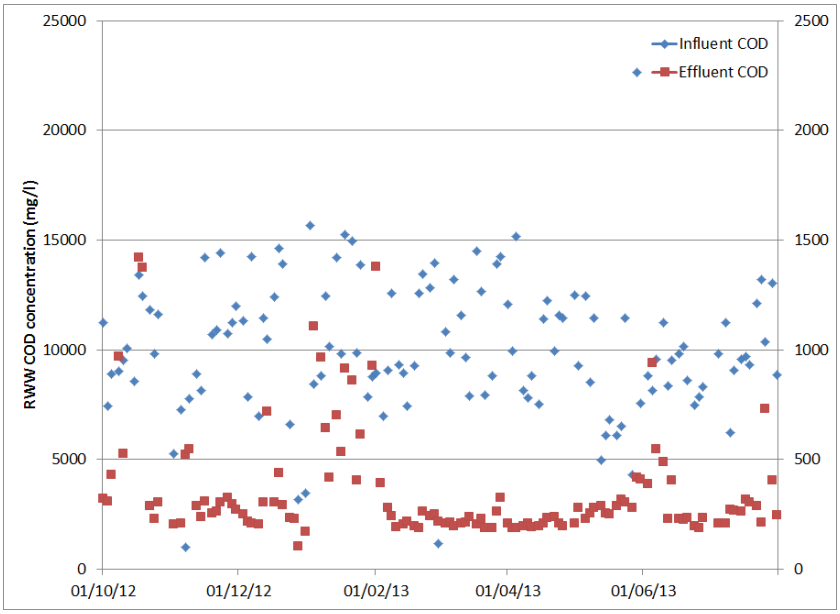


*Figure 6: Influent and Effluent COD concentrations for the AnMBR system at the confectionery manufacturing plant*

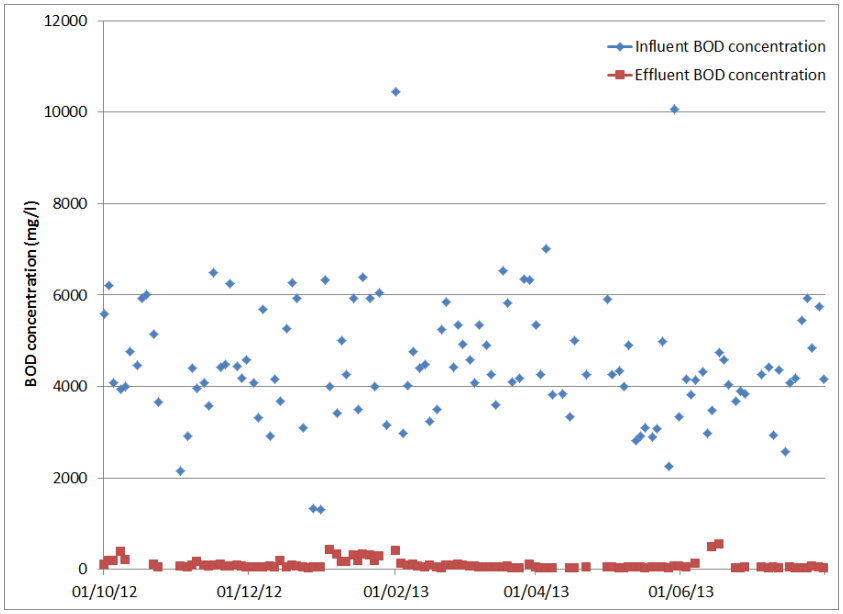


*Figure 7: Influent and effluent BOD concentrations for the AnMBR system at the confectionery manufacturing plant*

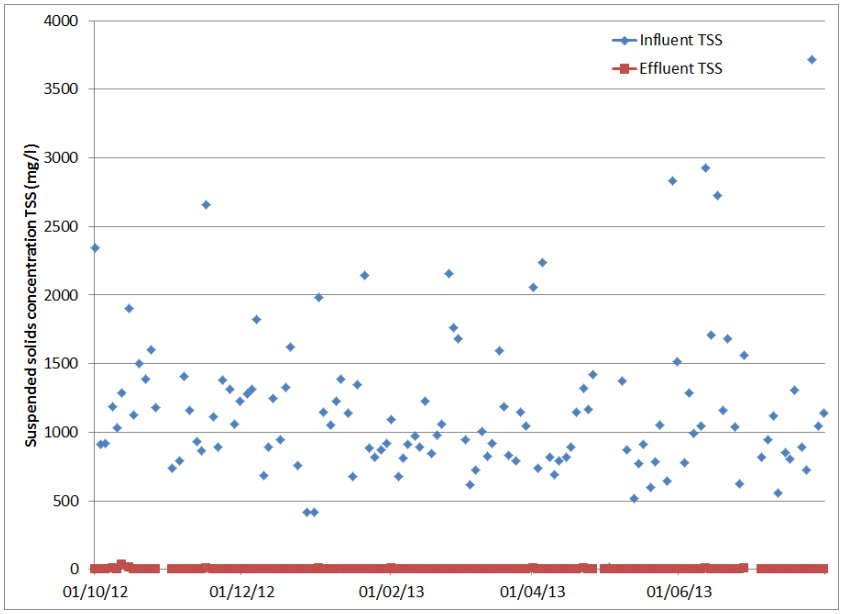


*Figure 8: Influent and effluent TSS concentrations for the AnMBR system at the confectionery manufacturing plant*

Figures 6-8 demonstrate that the AnMBR produces a high-quality effluent with COD and BOD removals greater 97 percent and TSS removal of essentially 100 percent. The previous anaerobic system provided COD and BOD removals of approximately 60 percent, under much lower loading conditions. Sludge setteability and odor issues in the open clarifier had been an ongoing concern with the previous system. Furthermore, the addition of co-products would not have been

possible with the existing system. The upgraded AnMBR system treats a much higher load and flow compared to the former treatment system, while discharging a much higher quality effluent to the local POTW.

The system has been in operation for over four years now, and there have been no membrane failures or replacements. Membrane cleanings are done typically once every six months.

Figure 9 demonstrates samples of the influent, mixed liquor, and effluent from the AnMBR. It also shows the superior quality of the AnMBR effluent compared to the influent raw wastewater.

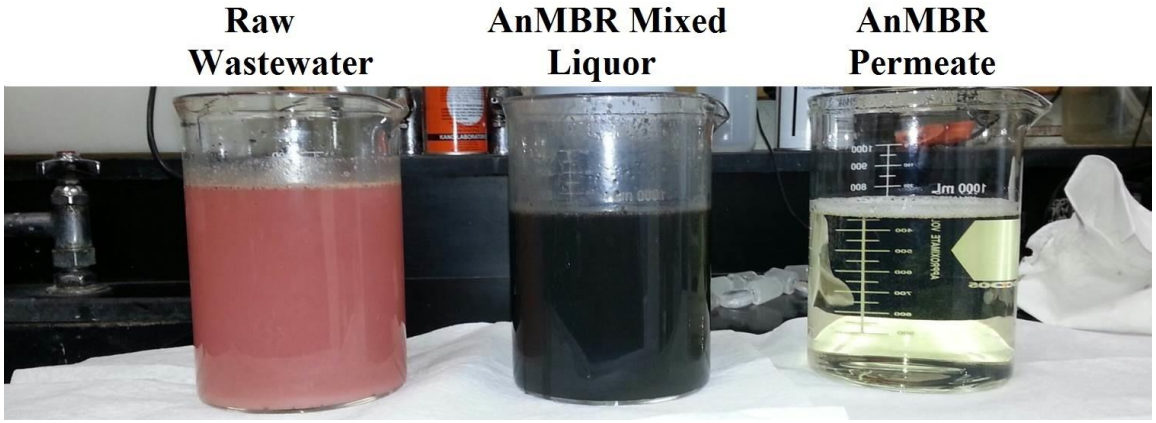


*Figure 9: AnMBR influent, mixed liquor, and permeate at the confectionery manufacturing plant*

### Conclusion

The AnMBR effluent consistently meets the effluent discharge limits with effluent BOD and TSS concentrations of <30 mg/l and <5 mg/l, respectively. This system is another proven example of how the AnMBR process can be integrated into an existing anaerobic system. Upgrading the system into an AnMBR increases treatment capacity, produces a much better quality effluent, and eliminates any issues and headaches associated with sludge settleability problems.

## Kellogg Company Pikeville Plant

### Introduction

Kellogg Company is the world's leading cereal company; second largest producer of cookies, crackers and savory snacks; and a leading North American frozen foods company. The existing wastewater treatment system at the Kellogg Company Pikeville Plant in Kimper, Kentucky, USA, consisted of an EQ tank, an anaerobic hybrid reactor, followed by an aerobic sequencing batch reactor (SBR). The existing system was unable to treat additional wastewater flow and load being sent to the system and had difficulty meeting the effluent limits.

Kellogg Company Pikeville Plant was in need of increasing the operating capacity of the existing system so that it could handle additional wastewater flow and COD load. The technology chosen

to treat the wastewater was an AnMBR followed by an ADI-MBR (aerobic membrane bioreactor) system. The AnMBR treats the majority of the organic load while the MBR offers aerobic polishing of the effluent prior to final discharge. This is believed to be the first AnMBR + MBR system installation in North America. The new system consists of a CSTR and covered membrane tank together as the AnMBR, and pre-aeration tank and membrane tank together as the aerobic MBR polishing stage. The submerged membrane cassettes are installed in a single modular steel tank with the anaerobic and aerobic membrane tank compartments separated by a common wall.

## Full-Scale Operating Results

The AnMBR was commissioned in March 2013 and is operating at mesophilic temperature conditions. The system temperature is controlled through existing spiral heat exchangers. The average temperature in the system is 36°C (96°F). The average pH in the AnMBR is maintained well at 7.0±0.1 for anaerobic sludge conditions.

*Figure 10: AnMBR + MBR wastewater treatment system at Kellogg Company Pikeville Plant*

Figure 11 displays the raw wastewater flow and COD load to the AnMBR system. The design flow for the AnMBR is 75 $m^3$/d (20,000 gpd).

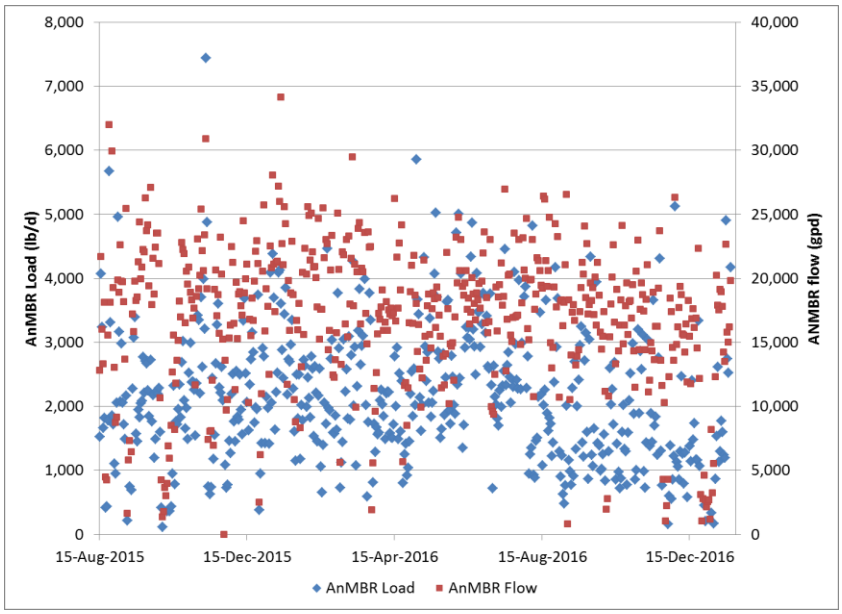


*Figure 11: AnMBR flow and COD load at the Kellogg Company Pikeville Plant*

The treatment of the wastewater to date has been excellent using both the AnMBR and MBR to meet the discharge limits for a local stream. Figure 12 presents the COD removal from the AnMBR and MBR systems. The COD removal observed has been 99.4 percent and the TSS removal is nearly 100 percent. The system has exhibited excellent BOD removal with the MBR effluent BOD concentration averaging less than 5 mg/l, which is well below the 40 mg/l BOD discharge limit.

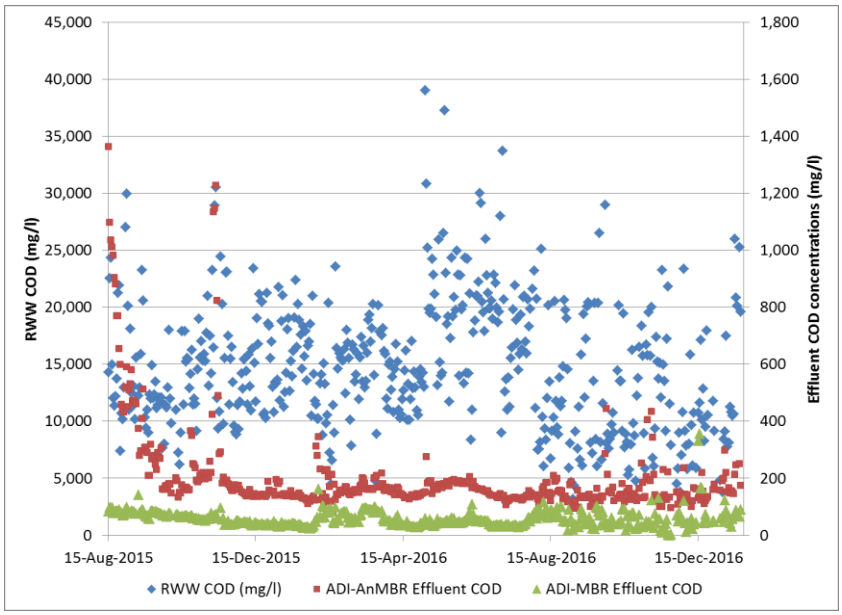


*Figure 12: Raw wastewater and effluent COD concentrations for the AnMBR + MBR system at Kellogg Company's Pikeville Plant*

### Conclusion

The Kellogg Company Pikeville Plant has a combination AnMBR + MBR system to treat the food processing plant's wastewater. The process effectively treats the wastewater removing greater than 99 percent of the influent COD, BOD, TSS, and FOG concentrations. This allows for final direct discharge of treated effluent to a local stream. The AnMBR + MBR system at the Kellogg Company Pikeville Plant is another example of a successful full-scale application of the AnMBR process, which is ideal for treating biodegradable industrial wastewaters with high SS and some FOG concentrations.

## Summary

The case studies presented in this paper highlight the benefits of AnMBR systems for treating food processing wastewater. Each of these plants demonstrate that the AnMBR process can be implemented to upgrade existing anaerobic treatment systems to increase treatment capacity while significantly improving effluent quality. This innovative anaerobic treatment technology is ideal for retrofits, upgrades, and space limitations, and in situations where significantly better effluent quality is required, sludge settleability issues are a concern, and/or high COD/TSS/FOG concentrations need to be anaerobically treated without primary treatment.

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