SUCCESSFUL PLANT SCALE WINERY WASTEWATER TREATMENT USING MEMBRANE BIOREACTOR IN NORTHERN CALIFORNIA

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ABSTRACT

In 2006 Hess Collection Winery (Hess) in northern California started up a new 37.8 m^3/d (10,000 gpd) membrane bioreactor (MBR). Wineries in Northern California have traditionally relied on wastewater treatment systems that are land intensive but require minimal operational assistance. Giving up land for wastewater treatment did not make economical sense for this winery. The compact footprint, superior effluent quality, and relatively low operational systems requirements of the membrane bioreactor made it an attractive option. Summit designed a MBR system which was started-up in November 2006. BOD_5 and TSS removal efficiencies of greater than 99 percent were achieved.

KEYWORDS: Membrane Bioreactor (MBR), 5-day Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Mixed Liquor Suspended Solids (MLSS).

INTRODUCTION

Hess is located in an industrial park in the City of American Canyon, near Napa, California. Prior to the installation of the MBR system, Hess trucked its wastewater to the treatment facility at their other winery in Napa.

Like a typical winery, Hess's wastewater consists of relatively high strength wastewater with BOD_5's ranging from 500 to 20,000 mg/L. The City of American Canyon's connection fees are based on BOD_5 , TSS and flow rate. Due to the high strength and flow rates, the cost of discharge of untreated wastewater to the sewer encouraged Hess to look at pre-treatment options.

Hess hired Summit Engineering to evaluate these options. Summit evaluated three options that could reduce the sewer connection fees:

a) Membrane Bioreactor (MBR)

b) Conventional Activated Sludge Process (ASP)

c) Facultative Treatment

The study concluded that an MBR would provide the highest level of treatment and superior effluent quality of the options examined, with typical BOD_5 and TSS levels less than 10 mg/L.

The MBR operation is simpler than ASP, primarily because a MBR system has a physical membrane for TSS removal and does not rely on the settling characteristics of Mixed Liquor Suspended Solids (MLSS) for ensuring desired effluent quality. As a result, operation of a MBR system requires fewer analytical tests and daily adjustments compared to an ASP based process. Typical ASP maintenance functions such as maintaining a constant MLSS concentration, Sludge Age, and/or Food-to-Microorganism ratio become less critical with an MBR system. There is also no clarifier or a return activated sludge (RAS) to operate and maintain in an MBR system.

The footprint for an MBR system was the smallest of the options considered. This was due primarily to the system's ability to keep high MLSS concentrations and no need for a clarifier. An ASP system would require a larger aeration zone, and a clarifier compared to an MBR system. A facultative treatment would require a large area to provide adequate residence time and volume for treatment.

Based on the above reasons, a membrane bioreactor system was recommended by the design engineer and approved by the owner. The proposed MBR system met the following goals for the winery:

- Compact footprint
- Superior effluent quality to reduce sewer discharge connection fees
- Lower operational assistance requirements compared to traditional aerobic treatment systems
- Partially automated operations
- Ease of future expansion
- Ability to meet nine month design/permitting/construction schedule

TITAN™ MBR system, manufactured by Smith & Loveless Inc., located in Lenexa, Kansas was selected. TITAN™ met the above goals for MBR. It offered following benefits:

- Factory built system
- Reduced equipment requirements
- Gravity flow through the membranes
- Ability to meet Hess's schedule

METHODOLOGY

Design Basis

Based on the available data, it was determined that two Titan MBR units from Smith & Loveless would be required to meet the peak and average discharge from the facility. The combined treatment capacity would allow for treatment of 37.8 m^3/d (10,000 gpd) flow from the winery. In order to optimize the sewer connection fees, an effluent storage/equalization tank was incorporated into the design to allow for collection and metering of the treated effluent to the sewer system. A belt filter press was incorporated in the design to minimize solids disposal costs by removal of excess water prior to offsite hauling.

Design Basis

Influent:		Effluent:	
Average flow	37.8 m^3/d	BOD_5	30 mg/L
Peak flow	56.8 m^3/d	TSS	30 mg/L
BOD_5	7,700 mg/L	pH	6 - 9

The compact installation was designed to fit within a 45 m x 20 m space next to their existing loading dock area. A containment wall was constructed in order to prevent wastewater from flowing into nearby storm drains in the event of catastrophic failure of the largest tank. Space for a third Titan MBR unit was reserved within this area should future winery expansion make it necessary.

PW Management System Component Overview

Hess's process wastewater (PW) management system consists primarily of wastewaters collected at floor drains and trenches within the winery, receiving, crush, tank, and wash down areas. No sanitary sewage is discharged into the PW management system. Exterior tank and process areas not under a roof are provided with diversion capability to provide a means of routing rainwater to the storm drainage system when those areas are not in use for process purposes.

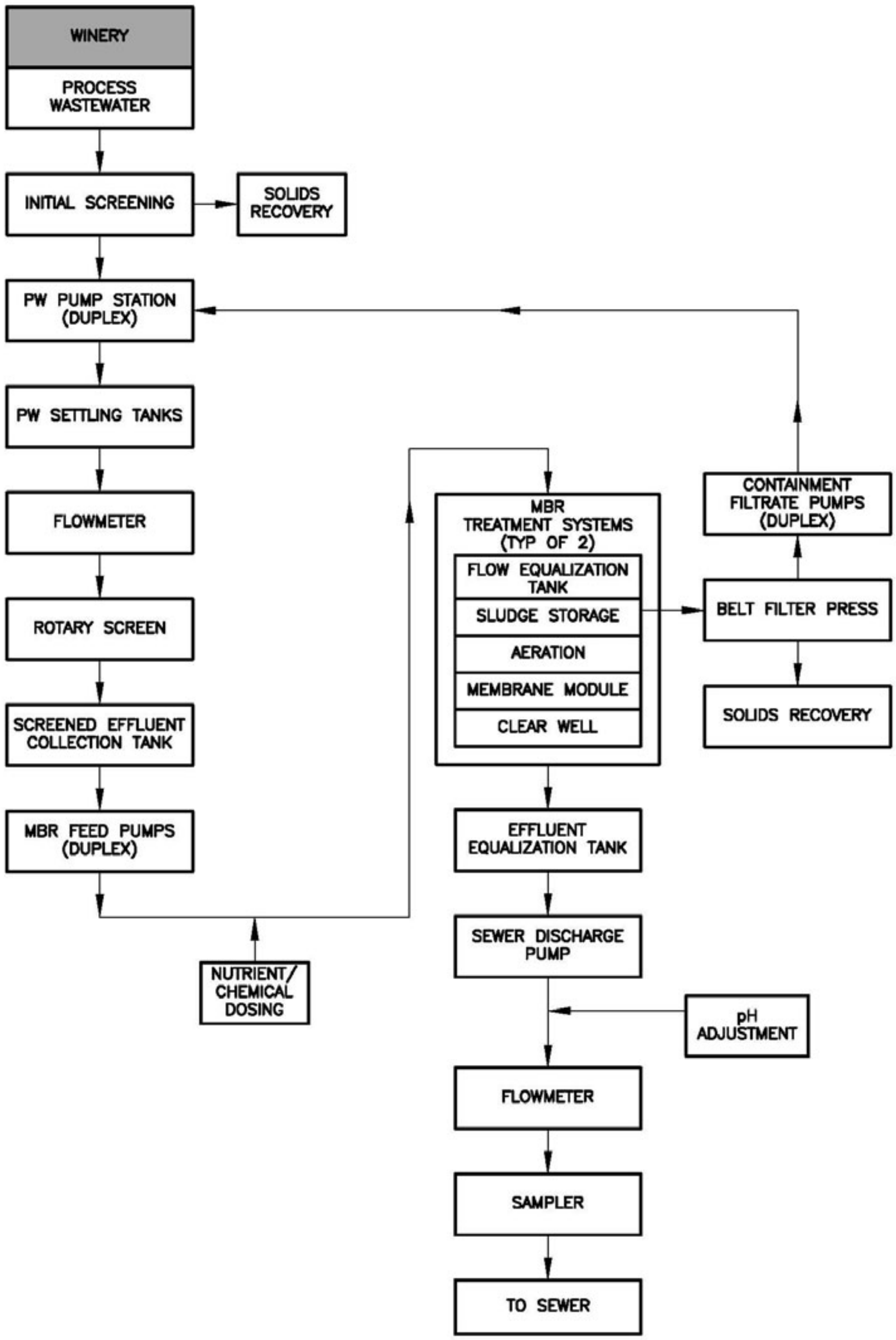

Figure 1 – Hess MBR System Flow Schematic

The following features comprise the process wastewater treatment system:

1) Initial screening – Provided by screened baskets and strainers installed on the trench drains and floor drains within the winery. Screen opening sizes are approximately 0.64 cm for exterior drains and 0.32 cm for interior drains.

2) PW Pump Station – An above grade pumping system pumps the PW to the PW settling tanks.

3) PW Settling Tanks – Two 23 m^3 tanks provide settling of large solids which are periodically removed.

4) Rotary Screen – A motorized rotary drum screen remove the solids larger than 3 mm. Solids from the screening operations are treated as pomace (residual grape solids). The rotary screen is activated by an inline flow meter.

5) Screened Effluent Collection Tank – A 3.8 m^3 effluent collection tank collects screened PW from the rotary screen and pumps to the MBR treatment system. Duplex MBR feed pumps the PW to the MBR system.

6) Chemical Dosing System – pH metering/control occurs prior to the MBR system as well as prior to discharge to the City Sewer system. Nitrogen and phosphorus metering also occurs prior to the MBR system.

7) Membrane Bioreactor (MBR) System – An MBR system consists of a bioreactor and microfiltration as one unit process which provides superior secondary effluent quality with typical BOD_5 and TSS concentrations at less than 10 mg/L.

   The S&L TITAN MBR system consists of a flow equalization chamber, sludge holding zone, and aeration zone with submerged membrane modules. The major components of the MBR package treatment system include 2 treatment units (each 18.3 m long, 3.7 m wide and 3.5 m tall) followed by one 315 m^3 effluent equalization tank. Following the screened effluent collection tank, PW is pumped into the flow equalization zone of the MBR system. Blowers are provided for the flow equalization zone and the aeration zone. The aeration zone with submerged membrane follows the flow equalization zone. The membranes (0.08 microns) are stacked within a fully submerged module in the aeration zone. Diffusers are provided beneath the membrane module. Sufficient membrane pressure is created by gravity that drives flow through the membranes. Clear water is drawn through the membrane while solids are retained in the aeration zone. The clean water is discharged into a clear well. The diffusers beneath the membrane module scour the membrane and provide oxygen to maintain aerobic conditions. The suspended solids from the aeration zone enter into a sludge holding zone where sludge wasting, thickening and decanting occurs.

   Effluent from the two MBR system modules is pumped to the 315 m^3 effluent equalization tank. An inline magnetic flow measurement device measures flows from each of the MBR modules to the clear wells. A duplex submersible pump system pumps the treated PW from the clear well to the effluent equalization tank.

8) Solids Handling and Disposal – Waste Sludge from the aeration zone is pumped to the sludge storage zone. Stored waste sludge is periodically pumped to a belt filter press (BFP) for sludge dewatering. The BFP is a Klampress® KP05 Belt Filter Press Skid manufactured by Ashbrook Corporation in Houston, Texas. The solids from the BFP are disposed of in a landfill. The filtrate from the BFP is sent to a containment/filtrate sump. This filtrate is then pumped to the PW Pump Station or to the effluent equalization tank. Duplex submersible pumps are utilized in the containment/filtrate sump.

9) PW Effluent Equalization Tank - Effluent from the MBR System flows to the 315 m^3 PW Effluent Equalization Tank from where it is pumped and discharged to the city sewer. The effluent pumps are float switch controlled. This tank provides adequate equalization so that discharge to the sewer can be controlled at the rate of 37.8 m^3/d or less. An inline magnetic flow measurement device measures the discharged flows from the Effluent Storage Tank to the city sewer.

PERMITTING AND INSTALLATION

An investigation of the sewer discharge requirements was performed to streamline the permitting process. Analysis of various treatment quality options was performed to allow Hess to base decisions on the economic tradeoff between a higher level of treatment and lower initial sewer connection fees.

A critical path analysis was prepared for Hess to understand the interactions between the design, permitting, installation, and start-up activities. In order to meet the timeline desired by Hess, the MBR system was ordered while design construction documents were being prepared. Coordination with the City of American Canyon occurred on a regular basis through the design process to expedite the plan review and permitting process.

The contractor, Ledcor, based in Napa, California, began sitework as soon as possible to facilitate the installation and timeline. Installation began in August 2006 and was completed in November 2006. Following installation, start-up activities were performed (see section below for more detail) by the system manufacturer and training of the winery staff was completed. Permitting was finalized through the City and the system was allowed to discharge to a City sewer.

Since January 2007, the MBR system has performed satisfactorily with consistent BOD_5 and TSS removal which meet or exceed discharge requirements. The facility is jointly operated by the winery maintenance personnel and an operational firm, whose role is described in a later section.

STARTUP

The two TITAN™ MBR plants were started up a day apart. The seed was provided by the local City's MBR plant. This helped in the startup because it provided a higher concentration of MLSS suspended solids at the time of startup. The two plants were filled to about two-thirds full. This brought the MLSS to approximately 7,000 mg/L within the aeration section. Clean water was then added raise the liquid level high enough for startup.

The MBR system from which the seed was obtained (City of American Canyon) is primarily a domestic wastewater processing facility. Hess MBR experienced some foaming very shortly after the aeration was begun until the bacteria adjusted to the new wastewater from the winery. The conditions that were causing foaming in the City's MBR were likely carried over to the Hess facility. The foaming was easily controlled by adding a de-foaming agent. It is important to use a de-foaming agent that is not silicon based because the silicon can permanently foul the membranes of an MBR. The de-foaming agent used for this startup was an alcohol based de-foaming agent that did not affect the membrane.

The two TITAN™ MBR units were initially fed winery wastewater at a rate of about one third to one half the design flow. Based on the effluent COD after one day of operation, indications were that adaptation of seed was not necessary. As a conservative approach, it was safer to build up the MLSS within the aeration tank before the full load was sent to the MBR units. Within approximately a week, the MBR was treating all of the winery wastewater that was generated at the facility.

Initially, the treated wastewater was hauled off site until testing confirmed that it was meeting the discharge requirements. The first set of tests showed that the BOD_5 and TSS were at the non-detect level and easily met the discharge limits. Following confirmation, the treated wastewater effluent was then directed to the City sewer and hauling was terminated.

OPERATION

Operations of MBRs are best accomplished when personnel have specific training related to the mechanical, chemical and biological processes that occur in the plant. Hess partnered with Heritage Systems Inc. (Heritage), a Napa California based corporation for operations assistance. Heritage holds licenses in wastewater and drinking water treatment and is experienced in the operation of these types of plants. Heritage visits the plant several times per week to collect compliance samples, review analytical data, make adjustments to the process chemistry and maintain on-line instrumentation. In addition, Heritage compiles all required laboratory data along with effluent flow and BOD_5 data each month. They prepare a report (required by the regulatory agency) each month that is reviewed, approved by Hess, and submitted. This partnership has resulted in a very well run and consistently in-compliance system.

During the startup phase, operating and analytical data collection was abbreviated to reduce cost and complexity. COD was measured and no BOD or TSS data were taken. Nitrogen and phosphorus samples were taken periodically to ensure that adequate nitrogen and phosphorus were available for optimum bacterial growth. Operating data were obtained from readouts on the human machine interface (HMI) and recorded on a daily basis.

After the MBR had been operating for a few months, the operating data was taken three or more times per week based on the operator's available time. The recorded MBR operating data included, but were not limited to, instantaneous flow, daily flow, flux, trans membrane pressure (TMP), permeability, dissolved oxygen (DO), and temperature. Analytical data taken once a week included but was not limited to influent and effluent BOD_5, COD, TSS, Total Kjeldahl Nitrogen, Ammonia, Phosphorus, and Nitrate.

Typical weekly maintenance activities include the following:

1. Wasting of the sludge (if needed) by manual transfer to the sludge holding tank in the MBR unit. Wasting of the sludge reduces the aeration tank MLSS levels and allows for decanting of the sludge.

2. Based on the analytical data collected in the previous week, adjustment to the chemical feed pumps were made (if needed) to provide sufficient macro nutrients for a healthy bacteriological population.

3. Verification that all chemical tanks (Nitrogen, Phosphorus, & pH adjustment) had sufficient chemicals for continued operation.

4. Visual verification of system components to make sure there were no obvious signs of leaks, inoperable equipment, etc.

5. Record critical operating information from the HMI screen.

6. Adjust aeration blower VFD speed (if needed) to maintain proper DO levels in the aeration zone.

AUTOMATION OF OPERATIONS

Plant operation is semi automatic. All pump stations are float switched controlled with high level alarms. The DO level in the aeration tank can be controlled by manually turning on blowers and changing the variable frequency drive (VFD) speed. Dewatering of waste sludge is initiated manually. All alarm conditions including pump malfunctioning, tank levels, and out-of-range process parameters are conveyed to a central alarm panel inside the winery. The analytical sampling is typically done on a weekly basis, not daily. The absence of clarifier significantly simplifies the operation. Typical daily sludge settling tests, waste activated sludge (WAS) adjustments, return activated sludge (RAS) adjustments and microscopic observations are not necessary.

RESULTS AND DISCUSSION

The results of this full-scale operation at the Hess Collection Winery showed that the MBR treatment technology is effective in processing wastewater from a commercial winery. Figure 2 shows the typical discharge flow over a one month period. With the average daily discharge of 23.1 m^3/d (6,100 gal/day), BOD_5 levels were reduced by over 99% from an average of 8,400 mg/L to less than 5 mg/L. COD levels were also reduced by over 99%, from an average of 17,000 mg/L to less than 50 mg/L. TSS levels were reduced by over 99% from an average of 1,250 mg/L to less than 10 mg/L. The influent COD/BOD_5 ratio was found to be 2.02. The peak influent COD, BOD_5, and TSS were found to be 91,200 mg/L, 20,000 mg/L and 8,300 mg/L respectively.

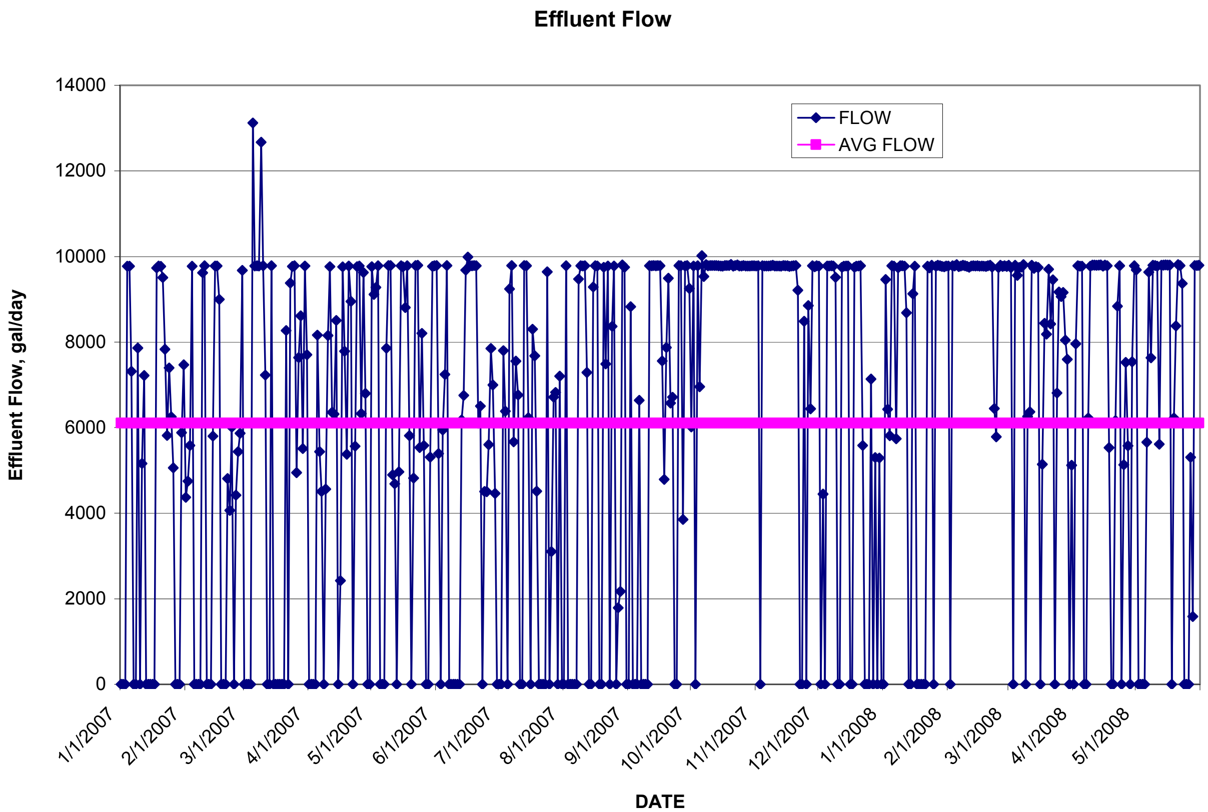

Figure 2 – Flow Data for Hess's MBR System

Effluent discharge is kept to less than 10,000 gallons per day per City's discharge permit. The average discharge flow is about 6,100 gallons per day.

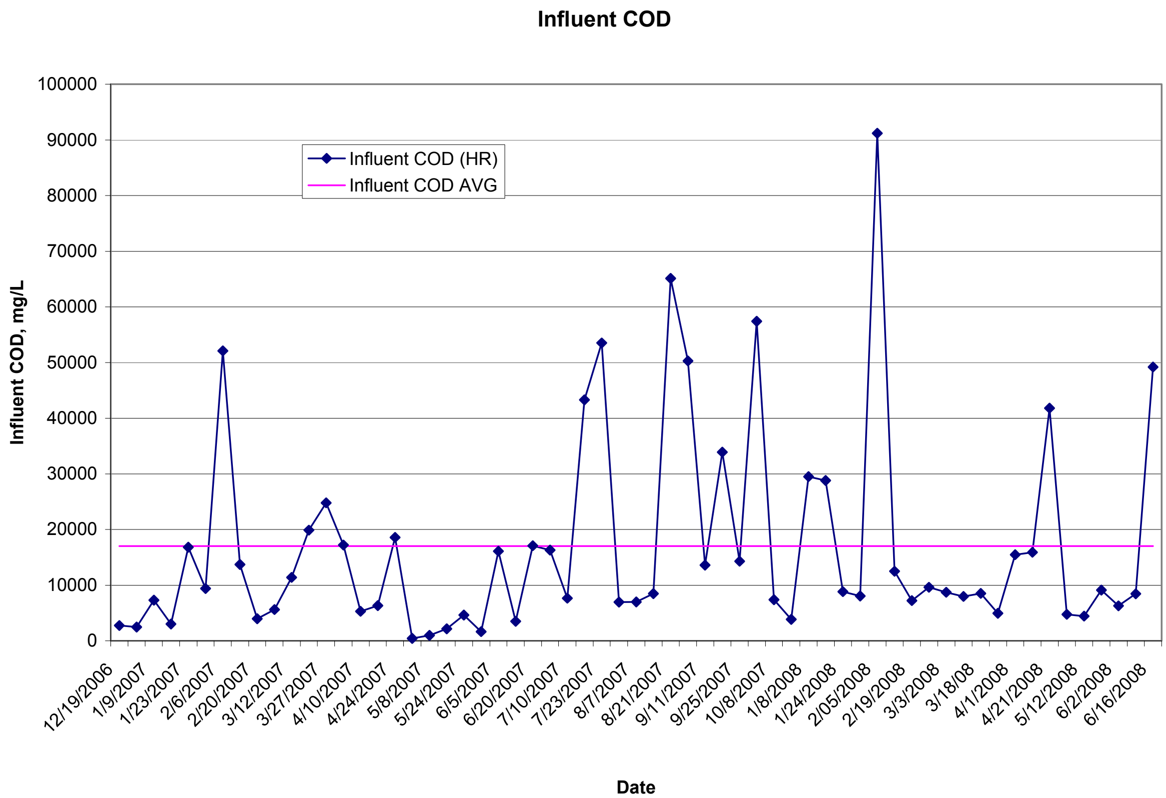

Figure 3 – Influent COD Data for Hess's MBR System

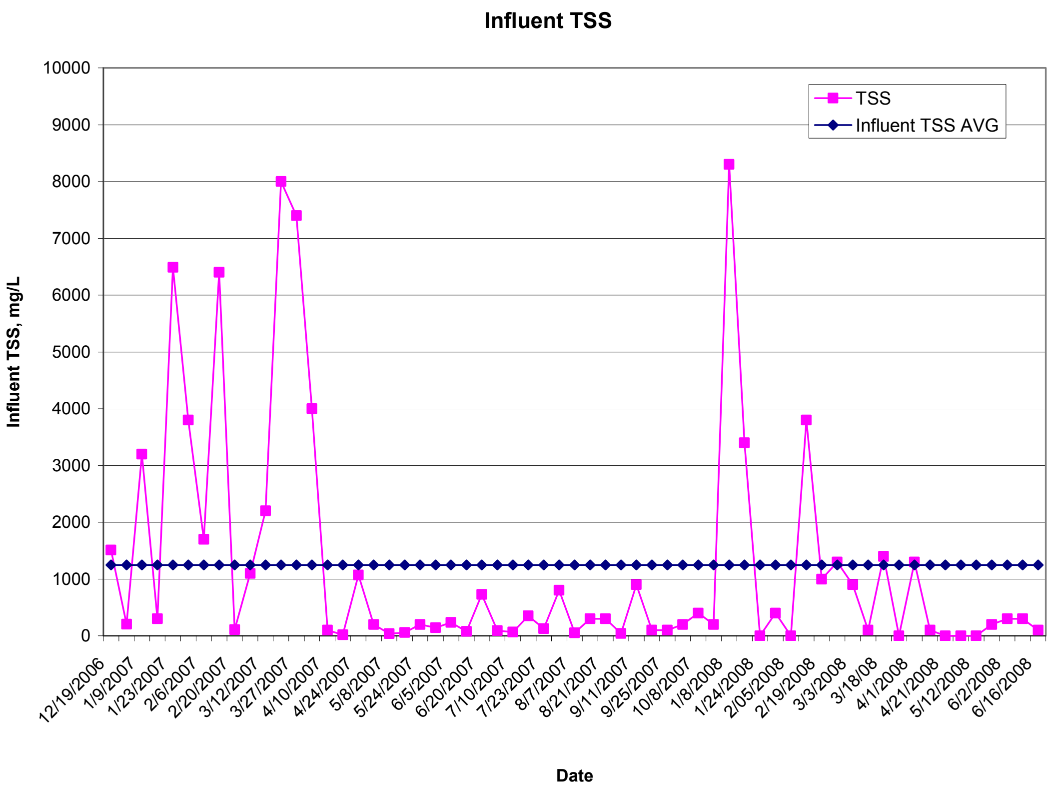

Figure 4 - Influent TSS for Hess's MBR System

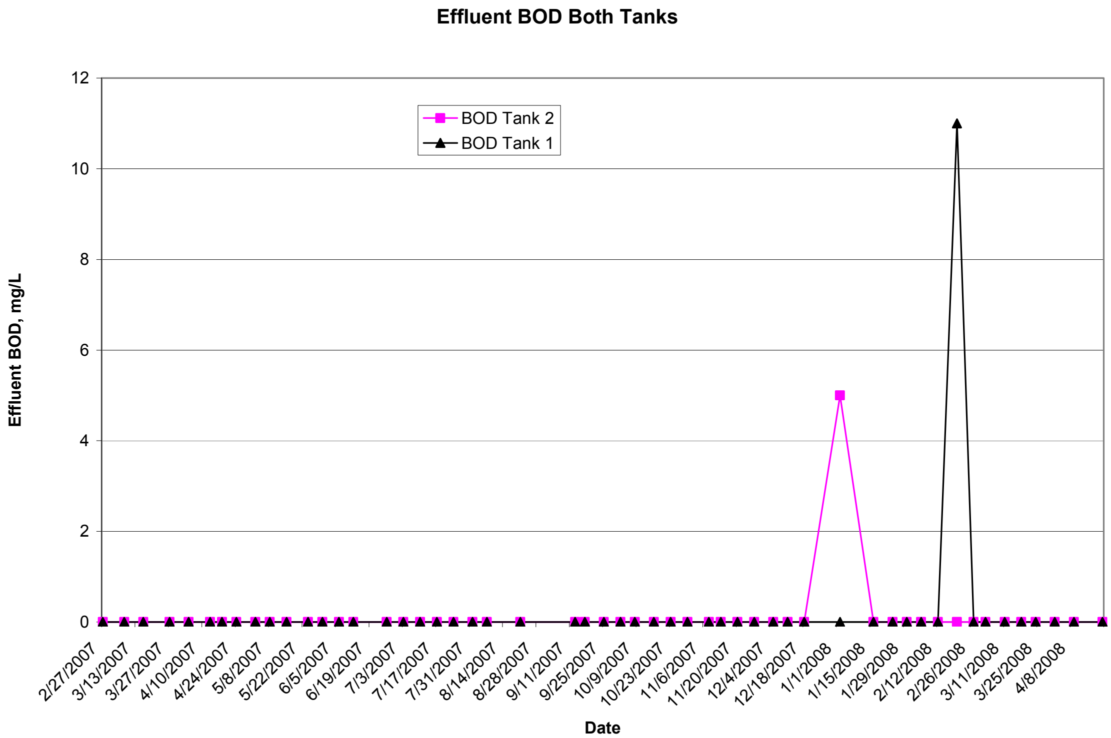

Figure 5- Effluent BOD_5 Data for Hess's MBR System

MBR Effluent BOD_5 is typically close to zero or non-detect, indicative of excellent system performance.

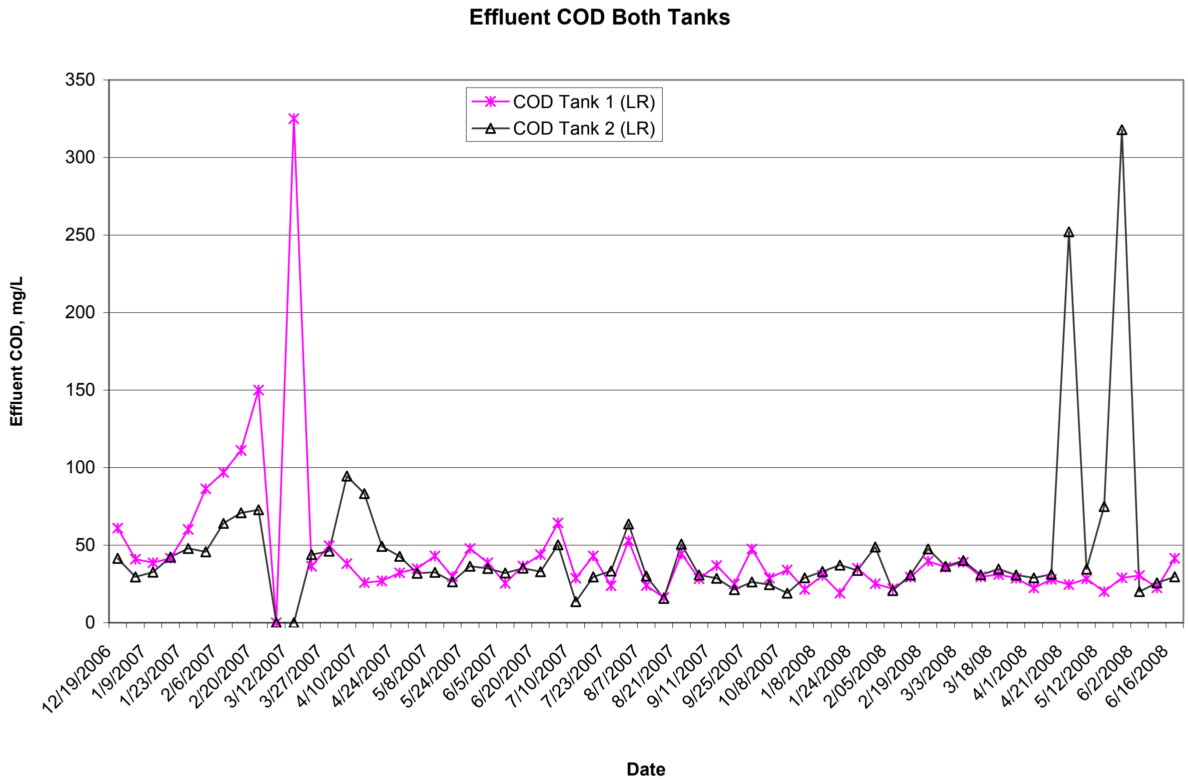

Figure 6 - Effluent COD Data for Hess's MBR System

Effluent COD is measured as a quick check of the effluent quality and is not part of the discharge reporting requirement.

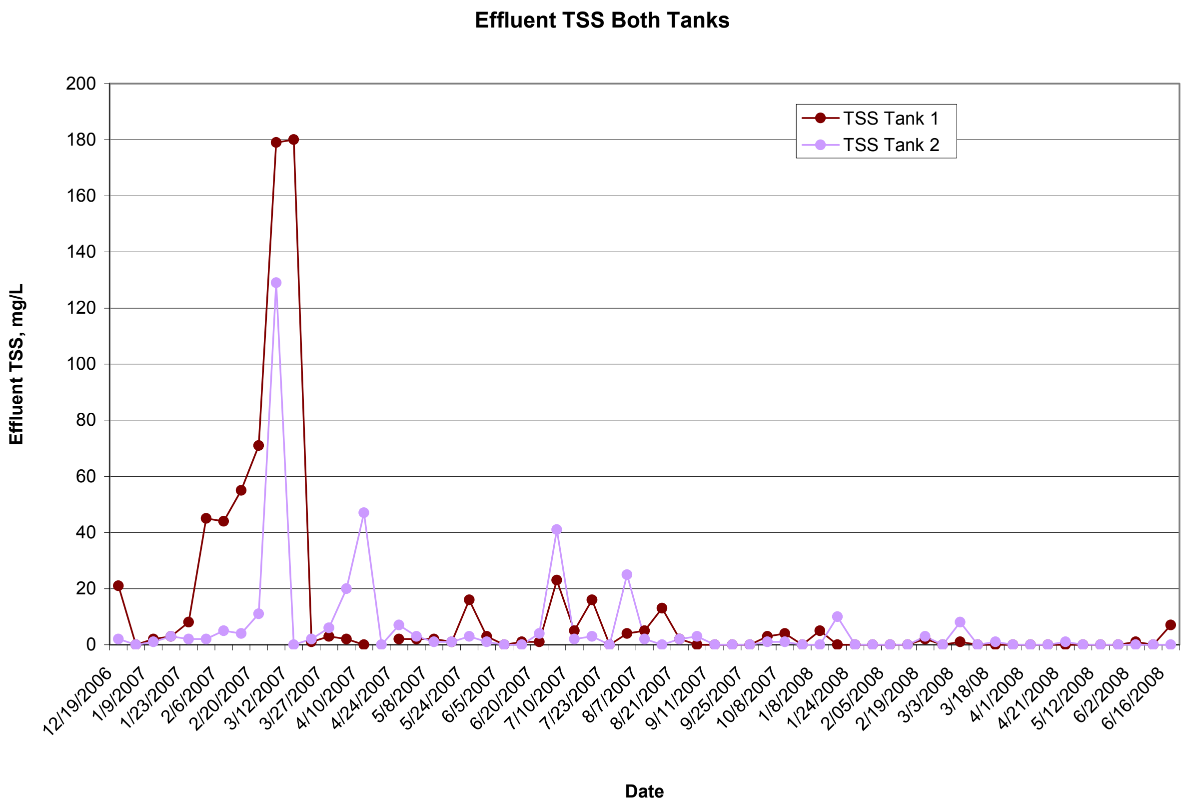

Figure 7- Effluent TSS Data for Hess's MBR System

After passing through the membranes, the increase in the effluent TSS is attributed to the algal activities in clearwell/effluent storage tank. The periodic spikes in the effluent TSS experienced during first nine months of operation are under control now.

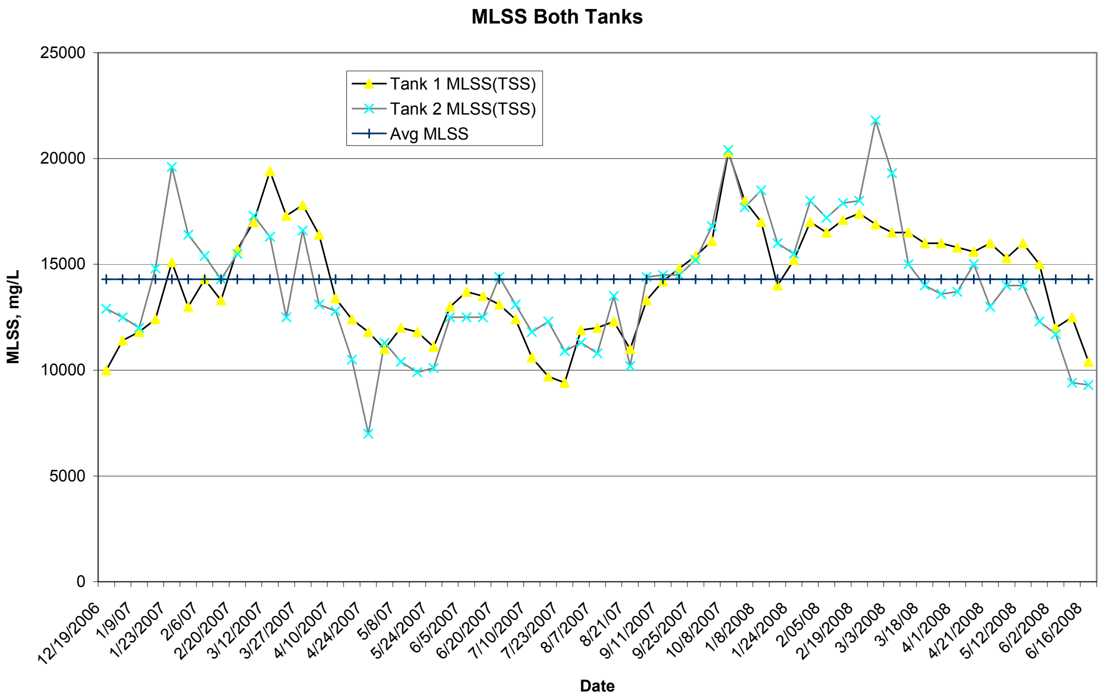

Figure 8 – MLSS Data for Hess's MBR System

MLSS concentration varied from 7,000 mg/L to 21,800 mg/L with an average of 14,150 mg/L. With an average flow of 23.1 m^3/d, BOD_5 of 8,400 mg/L, the average Food to Microorganism Ratio (F/M) was 0.051 g BOD_5/g MLSS/d. Figure 8 shows MLSS concentrations in both MBR tanks. MLSS concentrations were not critically controlled, but generally kept between 10,000 and 20,000 mg/L. No attempt was made to control the sludge age or the F/M ratio.

TRANSMEMBRANE PRESSURE (TMP) DATA

The TMP data over time for MBR-1 is shown in the figure below. The typical operating TMP is 0.5 to 1.2 psi. Note that there was a peak in the TMP early in the operation where the TMP went over 1.3 psi. This occurred when the DO dropped to zero. Early in this operation it was thought that the DO meter was not reading correctly because there was no indication that a peak load had been received. Then it was discovered that extreme high strength wastewater discharge had occurred and the influent BOD could have been much higher than expected. A portable DO meter verified that the installed DO meter was accurate and the membrane had become fouled due to low DO causing untreated wastewater to pass through the membrane. This figure shows that once the membrane was given a chemical clean of chlorine, it recovered and the TMP dropped to around 0.3 psi which was the about the initial TMP during the early stages of startup.

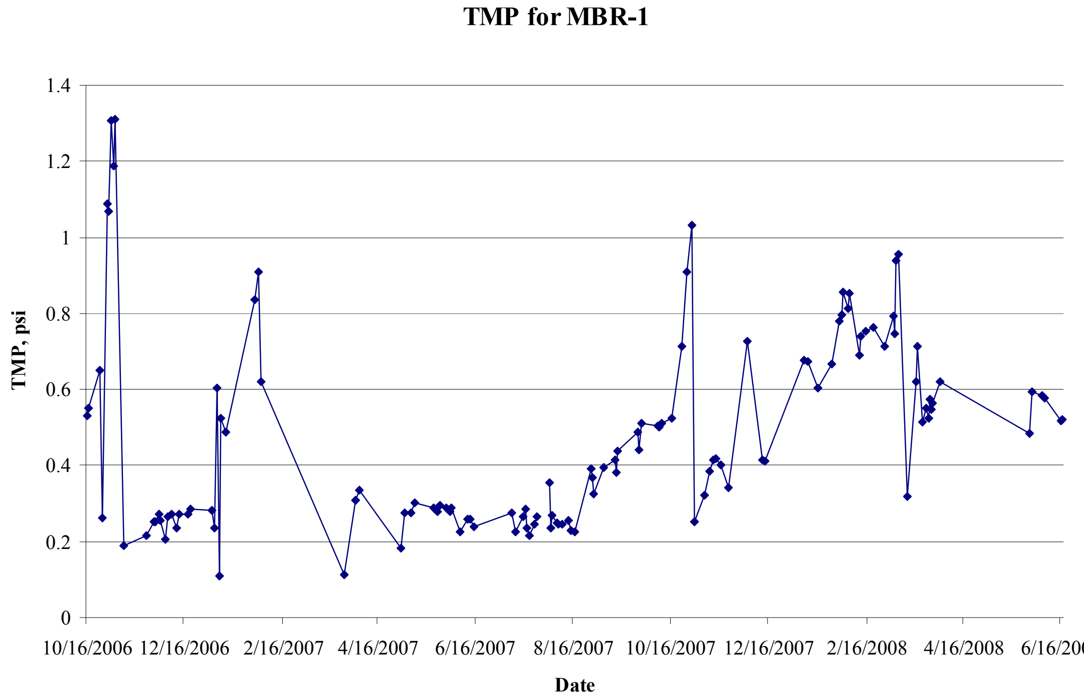

Figure 9 – TMP Data for Hess's MBR System (MBR No. 1)

MBR-2 received a similar slug of high BOD but did not exceed the oxygen capacity of the aeration system. This shows that even though the TMP rose to about 0.8 psi, the membrane did not become fouled to the extent that a chemical cleaning was necessary.

Although the expected TMP for these plants was 0.5 to 1.2 psi, the actual operating TMP ranged from 0.3 to 0.5 psi for most of the first year. Both MBR units were given chemical cleanings during this operation period as shown by the peak TMP values approaching 1 psi and then suddenly falling to a normal operating TMP. The chemical cleaning shown for MBR-1 in mid-October did not allow enough time for the cleaning to be completed and thus as shown on figure below the TMP began to rise more than expected shortly after the cleaning had been conducted. Because the TMP remained below 1.0 psi, an additional chemical cleaning was not given but will be cleaned in about six months if the TMP remains below 1.2 psi and does not require a cleaning sooner. The operation for MBR-2 was similar to that of MBR-1 with the exception of the first early cleaning required by BMR-1.

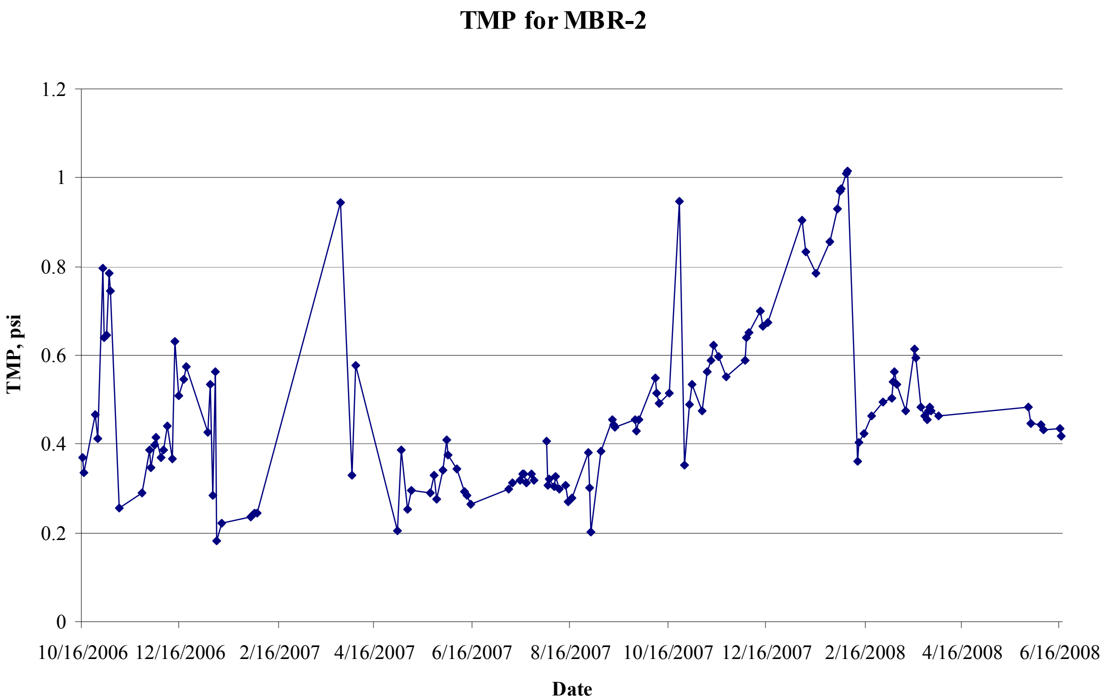

Figure 10 – TMP Data for Hess's MBR System (MBR No. 2)

CONCLUSIONS

The following conclusions were drawn from the design, construction, and operation of Hess Collection Winery's MBR treatment system:

- Start-up and long term operation of a Membrane Bioreactor treating high strength winery process wastewater was successful and met or exceeded all constituent treatment requirements
- 99 percent removal efficiencies were achieved for BOD_5, COD and TSS
- Effluent quality with BOD_5 and TSS levels less than 30 mg/L were achieved to exceed sewer discharge requirements and reduce sewer connection costs
- Installation of the system in a relatively small footprint reduced impact to the existing loading dock area
- Relatively simple operational process with limited testing requirements to meet superior effluent discharge requirements
- Partially automated operation to reduce the operational requirements placed on the winery maintenance staff and lowering costs related to the operational firm
- Design and construction tasks were streamlined to meet Client desires for quick implementation and start-up
- Modular system design allows for future expansion and increased wastewater treatment capability

FUTURE MONITORING

The MBR system at Hess will be monitored in the future with a goal of better understanding of the system kinetics. Summit is assisting with design and start-up of MBR systems at other wineries. Hess's MBR performance will be compared to other MBRs.

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