GOT MILK? GOT WASTEWATER TOO!
TREATMENT OF DAIRY PROCESSING WASTEWATER

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ABSTRACT

A major dairy processing operation owned and operated by the Michigan Milk Producers Association (MMPA) located in central lower Michigan was required to design and construct a process wastewater treatment plant within a 14 month period. The system is sized to treat up to 0.5 MGD of dairy processing wastewater at a biochemical oxygen demand (BOD) concentration up to 1,846 mg/L. Effluent from the treatment process is discharged to a relatively small receiving stream. The State of Michigan included very restrictive discharge criteria in the NPDES permit issued to MMPA for the new treatment process including a seasonal phosphorus limitation of 0.1 mg/L. Historical wastewater characteristics along with milk processing data from the plant were used to establish the treatment process basis of design. The treatment process was required to accommodate variable loadings due to seasonal and market fluctuations in the amount of milk received at the plant throughout the year. The treatment system incorporates preliminary equalization, activated sludge treatment using sequencing batch reactors (SBR), and secondary equalization prior to tertiary filtration. Selection, sizing, and procurement of the major treatment process equipment, prior to completion of the final design, was utilized to meet the aggressive schedule. This paper discusses the history of treatment alternatives used at the site, challenges involved in sizing a treatment system to accommodate a highly variable waste while meeting stringent discharge requirements, completing design and construction within an aggressive timeline, regulatory agency negotiations, and treatment system performance since start-up in early 2002.

KEYWORDS

Dairy wastewater, design/build, low level phosphorus, variable loads

INTRODUCTION

MMPA is a cooperative of approximately 1,900 dairy farmers who produce about 60% of the milk in Michigan. MMPA’s Ovid plant has been in operation since 1957 and is located in the Village of Ovid, in rural central Michigan northeast of Lansing. The facility is the largest balancing plant in the state, with the capacity to process up to 3 million pounds per day of milk into commercial dairy products such as non-fat milk powder, bulk liquid dairy blends, and bulk butter.
Wastewater treatment for the plant was accomplished using a spray irrigation system for land application of untreated wastewater since 1959. The wastewater was applied year-round to agricultural fields near the plant using a series of solid set sprinklers. The wastewater received treatment through site soils and seasonal vegetation prior to discharging to underlying groundwater and adjacent streams. In 1997, the Michigan Department of Environmental Quality (MDEQ) notified MMPA the current land application site was no longer a viable alternative for the treatment and discharge of the wastewater due to concern of maintaining surface water quality. The state was concerned that continued application would lead to degradation of stream quality due to nutrient enrichment, especially phosphorus. MMPA was required to investigate the extent of impact to the underlying groundwater and adjacent surface water, as well as develop a long-term solution for the treatment and discharge of the wastewater generated at the plant.

In 1998, MMPA secured a lease agreement to apply process wastewater to agricultural land located approximately three miles from the plant. The MDEQ granted a permit for year-round land application and groundwater discharge of untreated process wastewater. MMPA undertook the design and construction of a land application system to irrigate the process wastewater year-round. Construction of the system began in June 1999 and the system was operational in April 2000. This system consisted of eight center pivot irrigation machines applying wastewater to 132 acres. Concerns regarding odors and freezing during winter operations required MMPA to provide significant system modifications. To avoid the issues related to freezing during winter operations, it was decided to install a treatment system and pursue a surface water discharge permit under the National Pollutant Discharge Elimination System (NPDES).

A permit application was filed with the MDEQ, at which time it was determined the target receiving stream, the Maple River, was on the nonattainment list of water bodies for the State of Michigan. The cause for this listing was nutrient enrichment due to elevated background phosphorus levels in the receiving stream. The MDEQ initially set a very restrictive phosphorus limitation (0.1 mg/L) for year-round discharge to the river, but would consider a seasonal discharge to the river during the non-growing season at a maximum phosphorus concentration of 1 mg/L. The Maple River has a relatively low flow during the summer season in the area of the discharge. The Maple River flows used to develop effluent limitations in the permit were the estimated 95% exceedances flow of 6.1 cubic feet per second (cfs), a harmonic mean flow of 16 cfs, and a 90-day, 10-year low flow of 7.5 cfs.

To avoid the need to remove phosphorus to the proposed summer season level of, 0.1 mg/L, MMPA choose to pursue a blended permit. Treated effluent was targeted for crop irrigation from May through October and discharge to the Maple River for the balance of the year. Treatment system effluent would be directed to the river from November 1 through either April 1 or May 1 (depending on field conditions) and to the recently constructed spray irrigation fields during the remainder of the year. The combination of complying with both surface water and groundwater discharge limitations required a treatment system capable of removing the majority of incoming biological and chemical oxygen demand, conversion and removal of influent nitrogen to maintain a total inorganic nitrogen (nitrate + nitrite + ammonia nitrogen) concentration of less than 5 mg/L, and total phosphorus to less than 1 mg/L.
As a result of the blended permit requirements, an activated sludge system using SBR technology was selected. This process was selected because of the flexibility in operating conditions and its ability to meet the low total inorganic nitrogen (TIN). Design requirements for the system were: biochemical oxygen demand of 15 mg/L, total suspended solids of 15 mg/L, total inorganic nitrogen of 5.0 mg/L, and total phosphorus of 0.8 mg/L.

As start-up of the system approached in April 2002, it became apparent that significant resistance to the seasonal land application of the treated wastewater was mounting by neighbors of the irrigation fields. This resistance was a result of the community’s experience with the irrigation of untreated wastewater. Based on these concerns, MMPA opted to pursue a modification to the original treatment system design to allow year-round discharge to the river. To accomplish this, the MDEQ granted an extension to allow irrigation of treated wastewater to the original site, using the original solid set sprinkler system, until the spring 2005. A tertiary filtration system using continuous backwash filters was incorporated into the system to meet the seasonal low level phosphorus discharge limitation of 0.1 mg/L.

WASTEWATER CHARACTERIZATION

MMPA began wastewater sampling to support the design of the new treatment system in earnest in April 2000; however, routine wastewater sampling had been ongoing since 1997. Composite raw wastewater samples were collected weekly starting in 1997 and were submitted for laboratory analysis of BOD, TIN, total Kjeldahl nitrogen (TKN), and phosphorus. Other parameters were also added, intermittently, including total suspended solids and chemical oxygen demand (COD) to further characterize the raw wastewater. Daily effluent flow was also recorded. The raw wastewater results from this monitoring effort are presented in two forms on Figures 1 through 8. The first presentation is a simple xy plot of the data as concentration versus date of collection. The second presentation is a ranking of the results showing the probability of occurrence. This presentation approach was used to assist in visualizing the probability of certain concentration or flow conditions to occur.
Figure 1

Influent Flow Data
4/12/00 through 1/15/01

Figure 2

Cumulative Influent Flow
4/12/00 through 1/15/01
Figure 3

Influent BOD$_5$
1/14/97 through 3/14/00, Based on COD

Figure 4

Cumulative Influent BOD$_5$
9/16/97 through 3/14/00, Based on COD

Percent Less Than or Equal To
Figure 5

Influent Total Nitrogen
1/14/97 through 5/29/02

Figure 6

Cumulative Influent Total Nitrogen
1/14/97 through 5/29/02
The probability approach was found to be useful to both the design engineer and MMPA in understanding the wastewater characterization data. It was also useful in determining the required capacity of the treatment system. MMPA wanted to be able to accommodate the vast majority of occurrences of flow and parameter concentration, however; because of the costs associated with being able to treat all observed combinations, this was not feasible. The statistical plots were used to identify design points to accommodate approximately 90-95% of the observations recorded during the data gathering phase. The primary parameters of concern were BOD and flow; however, total nitrogen and phosphorus entering the treatment process also needed to be considered. Using this approach, the influent wastewater characteristics for system design were established as presented in Table 1. Required effluent criteria are also presented in Table 1.

Table 1 – Wastewater Treatment Plant Basis of Design

<table>
<thead>
<tr>
<th>I. Flow</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Average Day</td>
<td>0.4 MGD</td>
<td></td>
</tr>
<tr>
<td>Design Day</td>
<td>0.5 MGD</td>
<td></td>
</tr>
<tr>
<td>Hydraulic Maximum</td>
<td>700 gpm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. Wastewater Characteristics</th>
<th>Influent</th>
<th>Effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD$_5$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Average</td>
<td>1,300 mg/L</td>
<td>15 mg/L</td>
</tr>
<tr>
<td>Design Day</td>
<td>1,846 mg/L</td>
<td>15 mg/L</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Average</td>
<td>350 mg/L</td>
<td>15 mg/L</td>
</tr>
<tr>
<td>Design Day</td>
<td>350 mg/L</td>
<td>15 mg/L</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>62 mg/L</td>
<td>-</td>
</tr>
<tr>
<td>Total Inorganic Nitrogen</td>
<td>17 mg/L</td>
<td>&lt;5 mg/L</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>40 mg/L</td>
<td>&lt;0.1 mg/L (April-October) &lt;1.0 mg/L (November-March)</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Average</td>
<td>200 mg/L</td>
<td>-</td>
</tr>
<tr>
<td>Design Day</td>
<td>400 mg/L</td>
<td>-</td>
</tr>
</tbody>
</table>

The accommodation of spills within the plant was of particular concern in determining the sizing of the influent equalization tank. The monitoring data showed that the BOD concentration in the wastewater could vary considerably. While the dairy processing plant staff actively addresses spills within the plant, milk and milk products do contain a significant amount of BOD. The literature value for the BOD of whole milk as presented in Dairy Food Plant Wastes and Waste Treatment Practices (U.S. EPA, March 1971) is 104,000 mg/L. Therefore, spills within the plant can result in considerable changes in wastewater strength. To accommodate and equalize swings in flow and concentration, the design incorporated a 350,000 gallon per day equalization tank equipped with coarse bubble aeration to provide mixing and minimize the chance for the formation of anaerobic conditions.
SYSTEM DESIGN

The treatment system is comprised of an influent equalization tank, two SBR tanks, effluent equalization, and filtration prior to discharge. Biosolids generated through treatment are aerobically digested prior to storage and land application. Table 2 presents the volumes of each of the process tanks. Figure 9 presents a plan view of the treatment plant. The treatment system process flow diagram is presented in Figure 10.

Table 2 – WWTP Process Tank Sizing

<table>
<thead>
<tr>
<th>Process Tank</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent EQ Tank</td>
<td>330,000 gallons</td>
</tr>
<tr>
<td>SBR Tanks (2)</td>
<td>1,000,000 gallons each</td>
</tr>
<tr>
<td>Effluent EQ Tank</td>
<td>120,000 gallons</td>
</tr>
<tr>
<td>Sludge Digester Tank</td>
<td>550,000 gallons</td>
</tr>
<tr>
<td>Sludge Digester Tank</td>
<td>1,000,000 gallons</td>
</tr>
</tbody>
</table>

Figure 9

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5057
Michigan Milk Producers Association
Wastewater Treatment Plant
The SBR reactors were targeted to operate at a mixed liquor suspended solids (MLSS) concentration of 3,000 mg/L and volumetric loading of 29 lbs BOD/day/1,000 cubic feet of reactor volume. The SBR reactor tanks are 88 feet in diameter with a total depth of 24 feet and maximum working depth of 22 feet. The SBRs are equipped with a jet aeration system. A ferric chloride feed system is incorporated into the system design to enhance phosphorus removal.

A three-cell continuous backwash sand filter system for final effluent filtration is fed from the effluent equalization tank. During low flow periods at the plant the filters can be operated in a recycle loop drawing from and discharging to the effluent equalization tank using the effluent forwarding pumps. Each filtration cell has an area of 50 square feet and a sand bed depth of 80 inches.

SYSTEM CONSTRUCTION

Following the development of a preliminary design, the negotiation of permit conditions, and the authorization from the MMPA Board of Directors to proceed with the work, only 14 months was left to complete the design, construction, and commissioning of the treatment system. To meet this aggressive schedule, MMPA elected to complete the project using a design/build approach with the design engineer serving as the construction manager.

During the preliminary design, a project plan and a schedule were developed to identify construction and design activities that would directly impact the completion of the project. The two key activities identified were the procurement of long lead process equipment and the construction of the cast-in-place concrete tanks. Long lead process equipment was procured directly by the construction manager. This approach allowed procurement activities to run in parallel with design activities, and major process equipment was ordered prior to the completion of design. Because not all design details were determined at the time of the equipment purchase, the construction manager and the equipment supplier had to work cooperatively to resolve outstanding design and coordination issues as the construction proceeded.

To expedite the construction of concrete process tanks, the plant construction was bid as separate trade construction packages with concrete work being bid as a separate package and ahead of the other work. Work on the construction of the concrete tanks was proceeding prior to the selection of other trade subcontractors.

With the design engineer also serving as the construction manager, the processing and review of shop drawings for equipment and construction was expedited because there were fewer contractual parties between the equipment suppliers/contractors and the design engineer. This not only reduced the time frame for approval of equipment but also gave the design engineer more influence over the equipment that was furnished for the project.

OPERATIONAL EXPERIENCE

System start-up begin in April 2002. Each SBR tank was seeded with activated sludge obtained from a cheese manufacturing wastewater treatment plant. After addition of the seed microorganisms the residual MLSS concentration was approximately 300 mg/L. Process
wastewater addition rate to the reactors was slowly increased while monitoring treatment performance. The SBR MLSS concentration increased to approximately 1,000 mg/L by the middle of May 2002, and 2,000 mg/L by mid-June. BOD removal was quite good at 60 days into start-up with nitrogen removal improving as the MLSS concentration increased. Both reactors approached 3,000 mg/L MLSS by August 2002 and routine wasting of biosolids was underway. All wastewater discharged from the dairy plant was processed through the wastewater treatment plant by early July 2002. MMPA sponsored a community open house for the new treatment system in late July 2002 which was well attended by local residents. Plant tours were provided to demonstrate how the system operates.

SBR system basic operational set-points include three approximately equal cycles per day per reactor. Each cycle processes approximately 45,000 to 60,000 gallons or 1 to 1.3 feet per cycle in the tank. The aeration system is controlled by dissolved oxygen probes located in each of the basins. Nitritification and denitrification processes were well established by approximately three months into start-up. The plant is operated primarily on a COD basis due to the quick turnaround time for results. A correlation between influent COD to BOD was established to average COD x 0.65 = BOD with a range of 0.6 to 0.7 based on routine monitoring of the influent. A composite sample of the influent equalization tank is monitored daily for COD to determine current loadings to the system. The system was reliably meeting discharge criteria for BOD, TIN, and phosphorus at the <0.8 mg/L limit for seasonal discharge without filtration. Ferric chloride is added to the SBR tanks to assist in the removal of residual phosphorus to meet permit limitations. Treatment performance and normal start-up equipment and programming issues were resolved by fall 2002. Seasonal discharge operations were agreed upon with the MDEQ. During the period from May 1 through October 31 in 2002 through 2004 the effluent was spray irrigated on the original land application site while during the balance of the year the wastewater was discharged directly to Maple River.

Construction of the tertiary filters to allow year-round discharge to the river started in November 2004 with forming and pouring the concrete filter cells. System plumbing modifications and the installation of filtration equipment was completed in February 2005 with system start-up in March 2005. An additional ferric chloride feed point was installed at the filter influent along with provisions to add a polymer to aid in the flocculation and removal of the suspended solids through the filter.

Treatment system loading and performance were analyzed for the period of April 2005 through April 2006. Milk volumes handled at the dairy processing facility have increased since the treatment plant has been brought on-line. The treatment system basis of design predictions were evaluated against actual conditions. Flows and load for this 13-month period show the following:

- The design day flow of 0.5 MGD was not exceeded but was approached. Flow to the plant was at or below the projected annual average design flow of 0.4 MGD approximately 75% of the time. This data is presented in Figures 11 and 12.
Figure 11

Influent Flow Data
April 2005 through April 2006

Figure 12

Cumulative Influent Flow
April 2005 through April 2006
- Influent BOD concentration to the treatment system exceeded the projected design maximum approximately 10% of the time and exceeded the projected annual average approximately 30% of the time. These are presented in Figure 13. The pounds of BOD discharged to the treatment plant were analyzed in a similar manner showing the design day maximum loading being exceeded approximately 5% of the time and the annual average loading being exceeded approximately 20% of the time. The BOD loadings to the treatment system are presented in Figure 14.

Figure 13

Cumulative Influent BOD₅
April 2005 through April 2006, Based on COD

Figure 14

Cumulative Influent BOD₅
April 2005 through April 2006, Based on COD
• Effluent BOD never exceeded 12 mg/L and was below 5 mg/L for the vast majority of samples. BOD treatment was consistently very good. Suspended solids removals were also typically very good, with most results below 10 mg/L.

• Removal of nitrogen in the SBR system was also consistently good with the majority of effluent samples showing TIN concentrations below 5 mg/L. Minor upsets were noted in March and July 2005. The upset in July was traced to excessive wasting of biomass from the SBR reactors bringing the MLSS concentration down to below 2,000 mg/L. Once the reactor biomass concentrations were allowed to recover nearer 2,500 mg/L, nitrogen removal performance returned. Figure 15 shows the effluent TIN data.

**Figure 15**

**Total Inorganic Nitrogen Effluent Data**

*April 2005 through April 2006*

• The effluent discharge from the system has met the low level phosphorus effluent requirement during the period from April 1 through October 31 the majority of the time. Operating experience is developing with respect to feed rates for ferric chloride to both the SBR tanks and the tertiary filters. Ferric chloride use is approximately 90 gallons per day with approximately 60 gallons per day fed directly to the SBRs and the balance directed to the tertiary filters. Phosphorus treatment performance was reduced during July 2005. The exact cause is unknown; however, the excessive wasting of biosolids from the SBR reactors is believed to have contributed to the elevated phosphorus concentrations in the effluent. Figure 16 presents effluent phosphorus data.
System operators have recently allowed the MLSS concentration in the SBR tanks to increase to approximately 3,000 mg/L. This was the design MLSS concentration and current loadings to the system indicate the projected annual average loadings to the system in terms of BOD and flow are being realized the majority of the time. System control using an MLSS basis is easy to target and because of the fluctuations in production rates at the plant, simplifies operations for the operations staff. This approach should be appropriate as long as loadings to the plant stay near annual average conditions as predicted in the basis of design.

The system has been shown to be stable and has been able to accommodate significant swings in daily loadings. While very few exceedances of the design day loadings for BOD have occurred, significant variability on a daily basis has been noted. Releases of raw and finished product have significantly impacted loadings on a daily basis. Even with these incidences, treatment performance and compliance with permit requirements have been maintained the vast majority of time.
CONCLUSIONS

Resolving the issues facing the MMPA Ovid plant were complex. The project used an integrated approach involving a cooperative effort among the owner, engineering consultant, and state regulators to understand all the relevant issues and achieve a creative solution. As shown in the project, environmental regulations can be complex, continually changing, and apparently conflicting. A thorough understanding of the applicable environmental regulations was key to identifying both the constraints on, and opportunities available for, the final solution. The impact of the problem on the environment was understood and a good working relationship with the local community was established to obtain the best workable solution.

The entire Ovid community has a significant investment in this plant. Dairy farms in and around Clinton County, where the plant is located, have been developed over the years based on the plant’s processing capabilities. Dairy is the most important sector of agriculture in Michigan, generating 5.7 billion pounds of milk in 2000 with a value of over $800 million. There was potential for negative economic consequences and employment reductions, both locally and within the state’s dairy industry, if the Ovid plant ceased operations or was relocated. The role of this plant in providing Michigan farmers with an efficient means of marketing milk products and maintaining the livelihood of the local community was critical.

MMPA made a commitment to remain in the community and invest significantly to construct an environmentally responsible wastewater management system for their Ovid operations. The wastewater disposal method previously used at the Ovid plant was spray irrigation of aerated, but not treated, wastewater onto agricultural fields. Past operation during winter and early spring occasionally resulted in wastewater ponding that would reduce the land treatment efficiency and lead to odors. The new wastewater management system has been shown to be capable of reliably producing a stable effluent suitable for year-round discharge to the local river.

An agreement between the State of Michigan and MMPA required the treatment system to be implemented within 14 months. An aggressive design/build approach was used to achieve project completion within the allowable time. Major long-delivery equipment was specified and procured on the basis of a preliminary design. The design engineer worked cooperatively with equipment vendors to resolve equipment design details and questions as the design was finalized. The design engineer also acted as the construction manager, contracting directly with trade subcontractors and managing the construction process. The integrated design and construction approach allowed close coordination of project activities and was the only feasible approach to completing this project in the allowable time.

The SBR system combined with adequate pretreatment equalization of flows and loads along with final filtration using continuously backwashing filters has been shown to be an effective treatment system for dairy wastewater. A high quality effluent has been obtained from the system while accommodating variable flows and loads.