FEASIBLE AND COST EFFECTIVE MBR APPLICATIONS AN ENGINEERS EXPERIENCE

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Introduction

The use of MBR technology has been steadily growing in the wastewater industry. Initially the technology was being used on smaller plants. Over the past ten years the application has expanded more widely and to larger plants.

This paper presents three projects that have been implemented in Ohio with the MBR activated sludge technology. The first plant has been operational since 2005, for nearly ten years and has a capacity of 25,000 gallon per day. This is the Rio Grande Estate WWTP which treats wastewater from 35 residences in Lake County, Ohio. The second plant located in Chesapeake, Ohio has a capacity of 1.8 mgd average daily flow, peak day flow of 5 mgd and has been operating since 2009. This plant, named the Union Rome Lawrence County WWTP, treats flow from the townships of Union and Rome in Lawrence County, Ohio along the Ohio River Valley at the southernmost part of Ohio. The third plant located in Canton, Ohio is presently being constructed and has been in planning and/or design since 2009. Construction began March of 2014. This facility, the Canton WRF has an average day flow capacity of 39 mgd and has experienced peak day flows as high as 110 mgd. The peak day design flow is 88 mgd. Present annual average day flow is approximately 26 mgd. This plant is one of, if not, the largest MBR activated sludge plant being constructed in North American and will be one of the first plants in Ohio utilizing BNR treatment to achieve total nitrogen limits.

Ohio has approximately 15 MBR activated sludge plants operating since 2005. The Rio Grande Estates WWTP was the first membrane plant approved by Ohio EPA and constructed. The reasons for using MBR activate sludge are many and they extend beyond the common idea that MBR should only be used when high quality effluent is required or when the site is small and a small footprint treatment technology is needed. Often times the overall life cycle cost of MBR activated sludge is lower than other treatment technologies, or new costly tank construction can be reduced or eliminated, upgrades can be built in existing structures, reduced impact to site development on new plants or expanded plants, O&M cost can be less expensive, operations can be simplified, process units can be reduced or eliminated and membrane thickening in the sludge process can significantly reduce operating hours and cost. Odors can be controlled, construction simplified, site piping and development can be reduced and facilities can be consolidated to single centralized support areas.

Many people also say MBR activated sludge is too expensive to construct and operate. Here in Ohio, this engineer has found that plant improvements utilizing MBR activated sludge can be constructed for a total plant improvement cost between $3.00 per gallon to $15.00 per gallon, unlike the commonly quoted price around the county of $20.00 per gallon to $40.00 per gallon. Perhaps the cost difference is associated with this engineers approach to educate the Owner of the different membranes available, pre-select the membrane system allowing the suppliers to propose their best system based on their established design parameters for the site specific conditions, or allowing multiple suppliers to propose and using a Best Value Evaluation to review the proposals based on the entire plant improvement taking into consideration all processes including preliminary treatment and sludge handling, and eliminating the use of weighting the selection criteria. Allowing the Owner to choose the membrane supplier based on the process that they feel is best suited for the facility.

The Rio Grande Estate WWTP was designed by a colleague of the author whom worked for another firm. Being involved with MBR activated sludge design, construction and operation since its first use in Ohio, the writer maintains contact with the County to monitor operations. The other two projects herein are projects conceptualized and designed by the writer.

Rio Grande Estates WWTP

Owned and operated by Lake County in northeast Ohio, this plant was built to treat wastewater from a subdivision of 35 residences. The MBR technology which utilizes submerged membranes in the activated sludge tanks to separate the solids from the liquid, eliminated the need for secondary settling tanks and sand filters whereby the site footprint was reduced and the ascetics of the plant enhanced to be more like part of the subdivision. Other benefits include the high quality effluent, simple construction and operation, completely covered treatment process to reduce odors, reduced operator maintenance and less land use on the initial site leaving room for the expansion.

The 25,000 gallon per day MBR treatment plant consists of three buried precast tanks with only the tops exposed and a small building which looks much like an out building in the subdivision. Precast tanks are used for the preliminary treatment plus equalization, the aeration tanks and the membrane basins. The membrane basin is divided into two separate units each having one cassette of Kubota by Enviroquip (now Ovivo) membranes. Hatches on the top of the precast tanks provide access to the process units. The building houses the motor control equipment, 3 blowers (2 duty, 1 standby), permeate pumps (2 duty, 1 standby), chemical feed equipment and disinfection system and a PLC for plant control. The plant control system is linked through the internet and plant operations are continuously monitored remotely.

The wet stream process consists of a grit, gravel and grease trap prior to a one dimensional 2 mm bar screen followed by equalization. Flow is pumped from equalization to the aeration tanks, then flows by gravity to the membrane basins. Permeate is removed from the membrane by the pumps in the equipment building. The pumped permeate is disinfected prior to being discharged to a nearby receiving stream. Sludge is held on site in the process tanks by allowing the MLSS concentration to fluctuate between 12,000 mg/l and 16,000 mg/l. The effluent is consistently below the NPDES permit limits; CBOD – 10 mg/l, SS – 12 mg/l, Ammonia less than 3 mg/l.

In the past and presently the plant influent wastewater flows typically range between 9,000 gpd and 16,000 gpd. Peak flows have reach 20,000 gpd. Although operations are monitored and controlled remotely, a County operator visits the plant daily, Monday through Friday and one day over the weekend, for approximately 2 hours each visit. While at the site the operator visually monitors each process operation, checks equipment and takes readings of process parameters. MLSS are monitored weekly and used to control the sludge inventory which typically results in approximately 1,000 gallons of sludge being hauled off site once a month. Other annual maintenance includes performing a biological cleaning of the membranes twice per year and inspecting the tanks once per year. The membranes have never had a mineral clean since originally installed.

The Owner provided some operation and maintenance costs for the plant and a conventional plant of approximately the same capacity. The cost information is provided as MBR Plant / Convention Activated Sludge Plant for each items. Electricity - $657.00 per month/$725.00 per month. No water or gas is used on the plants site. Heating of the buildings is electric. Approximately 20 gallons of sodium hypochlorite is used annually for membrane cleaning. Operator time is usually at least twice as long at the conventional plant as compared to the MBR plant. Long term maintenance since start up consists of replacement of one failed blower in year 10 and replacement of 50 percent of the membranes in year 10 (2014). Replacement of the remaining 50 percent of the membranes is planned for 2015.

Union-Rome Lawrence County WWTP

The Lawrence County Commissioners authorized the design and construction of a MBR Activated Sludge WWTP after preparation of a general plan which evaluated possible feasible treatment alternatives. After screening of available technologies, three process alternatives were evaluated based on life cycle cost. These three technologies were conventional activated sludge, vertical loop reactor and MBR activated sludge. The life cycle cost of conventional activated sludge was well above the other two. Vertical loop reactor and MBR activated sludge was within 10 percent of each other.

Although the MBR activated sludge alternative was slightly higher than vertical loop reactor, the Owner selected the MBR activated sludge due to the smaller footprint, less construction and high effluent quality. The existing treatment process consisted of cyclone grit removal followed by static screens, then trickling filter tower constructed of hardwood media followed by activated sludge tanks and secondary clarifiers. Post treatment was chlorine disinfection and post aeration before discharging to the Ohio River. The NPDES limits for the plant were CBOD – 30 mg/l; SS – 30 mg/l and no ammonia limit. A requirement of the permit was to perform and satisfy Acute Toxicity Testing of the effluent. The existing treatment process was unable to satisfy this regulatory requirement due to the fact that the treatment process in place created ammonia whereby the ammonia leaving the plant was greater than in the influent ammonia. The Owner also embraced the MBR technology as related to process control, fewer process units to operate, and maintain while achieving a high effluent quality. The Owner was also experiencing excessive manpower and high operational cost for the existing sludge treatment operation. Another difficulty was odors and equipment deterioration in the preliminary treatment building due to the high concentration of hydrogen sulfides from the influent flow. The planning study determined that design flows needed to be increased immediately from 1.0 mgd to 1.8 mgd and a future of 2.7 mgd. Peak flows were to be increased to 5.0 mgd immediately and 7 mgd for future. NPDES permit limits were to be lowered from CBOD – 30 mg/l to 10 mg/l and SS – 30 mg/l to 12 mg/l, ammonia limits of approximately less than 3 mg/l would be enforced with the improvement and future phosphorus limit are expected.

The membrane supplier was selected by a Best Value Evaluation. Enviroquip at the time now Ovivo and Zenon at the time now GE, were asked to submit proposals. The Best Value evaluation reviewed the membrane supplies proposals, considering all beneficial aspects of the submitted system plus the total project life cycle cost. The evaluation prepared by the engineer was provided to the Owner for the final membrane process selection. The Owner selected the Kubota membranes by Enviroquip process system based on a less expensive for capital cost, life cycle cost and in the Owners view provided the most benefit to the project.

The new treatment facility consisted of a new influent building with ¾ inch one dimensional coarse screening and septage receiving. After screening, flow enters a wet well which was adjacent to a dry pit submersible pump station which discharged to a preliminary treatment facility consisting of 3 mm perforated fine screens followed by a stacked tray vortex grit removal and a grease well. Because of the high hydrogen sulfide concentration in the influent flow the screen room, wet well and preliminary treatment rooms are pressurized with a high volume of air. This air volume is pulled from the rooms and put through a biological air control system for the removal of hydrogen sulfide and odor control.

From the grease well, the influent flow enters a pipe at the bottom of the well and flows to the MBR activated sludge process. The activated sludge process treatment unit consist of four process trains. The middle two trains treat the present design flow. One process unit is not used and is reserved for future. The fourth unit has been designed as an aerobic digester for sludge digestion and membrane thickening. Permeate is withdrawn from the membranes with horizontal split case permeate pumps that discharge to a UV disinfection system then through an effluent pipe. The effluent pipe is configured to split part of the flow to the non-potable water system and the remainder of the flow discharges to the existing post aeration tank and then to the Ohio River.

Because of the location of the plant to the adjacent residential neighborhood, the Owner requested the process units be enclosed. The entire treatment process from the influent screening room to the end of the activated sludge process was constructed in a single structure completely enclosed in a building which has a foot print of approximately 220 feet long and 100 feet wide.

Other improvements included in the project and associated cost included converting the existing activated sludge tanks, secondary clarifiers and a portion of the existing aerobic digesters to wet weather equalization. The remaining existing digesters can be used for wet weather equalization or sludge storage. The new aerobic digesters have a volume approximately one fourth of the existing digesters. The existing belt filter press was removed and a new dewater facility with new press and load out was installed in the existing preliminary treatment building. The Administration Building was expanded, on site fuel storage was added, a new generator was installed and an alum system was installed in anticipation of phosphorus limits. Existing structures no longer being used were demolished and the site was reconfigured with storm sewers, sanitary sewers and other utilities for the new plant.

The plant has been successfully operating since start up in 2009. The daily operator monitors operations from a room nested between the activated sludge area and the preliminary treatment area with windows providing view into the process areas. The plant staff consist of three operators whom are on site during the day with rotating shifts. The plant is locked down at night and is monitored and controlled remotely. These operators are responsible for all duties at the plant. The membrane thickening and new belt filter press has reduced the sludge operations from 5 days a week to 3 or 4 days per month. Dewatered sludge cake is hauled to a landfill by the same operator running the dewatering unit.

This facility, build with MBR activated sludge and aerobic digestion using membrane thickening including all improvements mentioned cost approximately $22,000,000, or under $12.50 gallon of wastewater treated based on the current average day design flow.

Canton, Ohio Water Reclamation Facility

In 1994, the City of Canton, Ohio had a general plan prepared which identified a two phased improvement implementation. Phase 1 implemented in the late 1990's changed out the influent screens, added primary and secondary clarifier, updated valve operators, updated the process control system and upgraded some chemical systems and other ancillary components such as the non-potable water tower pumps and mechanical systems throughout the plant. This improvement was primarily a capacity upgrade from average daily design flow of 33 mgd to 39 mgd in accordance with the general plan. Peak flow through the plant was designed to 88 mgd through primary settling. Activated sludge, secondary settling, tertiary treatment and post treatment was limited to 67 mgd due to the limiting hydraulic capacity of the improved secondary settling tanks and existing tertiary filters. The loading to the activated sludge tanks was below design and the existing tanks were of sufficient size to treat 67 mgd. Flows in excess of 67 mgd, which seldom occurred, would be equalized in three of the eight primary tanks which would remain offline until a wet weather occurrence.

The general plan stated that the Phase 2 Improvements should occur when loadings increase requiring more active sludge treatment or nutrient limits become more stringent. Postponing the Phase 2 improvements until these criteria emerged eliminated the need to construct costly activated sludge treatment basins, additional secondary settling tanks and expand tertiary treatment.

In 2009, Canton authorized a planning study for an improvement to address upcoming NPDES limits requiring removal of phosphorus and total nitrogen. Permit limits are CBOD – 10 mg/l, SS – 12mg/l, P – less than 1.0 mg/l and Total Nitrogen – 8 mg/l. This study, after screening possible process technologies, finalized on three technologies for life cycle cost evaluations. These three technologies were advanced BNR activated sludge, IFAS, and MBR activated sludge. Each alternative life cycle cost evaluation was to include necessary upgrades to preliminary treatment for the process technology, upgrading the secondary and tertiary treatment processes to treat a peak hydraulic capacity to 88 mgd, replacement of deteriorated unit process equipment and demolition of the incinerators and any structures not used in the new plant design. Of the three process technologies, IFAS had the highest capital cost and life cycle cost. The advanced BNR activated sludge process capital cost was nearly $25,000,000 higher than MBR activated sludge. The life cycle cost difference between advanced BNR activated sludge and MBR activated sludge was negligible. The MBR activated sludge process could be constructed in the existing 6 aeration tanks designed at a peak capacity of 88 mgd. The other two alternatives required construction of secondary treatment facilities, secondary settling tanks and tertiary filters.

The Owner choose to preselect the MBR process. Ovivo and GE were invited to propose. Ovivo proposed and GE choose not to submit. A Best Value Evaluation was prepared based on the submitted proposal to ensure that the Ovivo submittal satisfied and met the planning study considerations. The evaluation was provided to the Owner. The Owner selected the Ovivo proposal and pre-purchased the system separate and apart from the General Contractor.

The final design of the Canton WRF Nutrient Improvement Project consists of maintaining the existing influent pump station rated for 110 mgd, demolishing two of four existing detritus tank and converting the remaining two to a parshall flume. The existing pre-aeration tanks will be gutted and modified. Four trains of longitudinal grit and grease removal units and a screen building with two stage fine screening will be constructed within the existing tanks. A preliminary treatment solids building will be constructed adjacent to the preliminary treatment process. Equipment in the primary tanks will be removed and the tanks will be converted to Stage 1 equalization. Dewatering and recirculating pumps are included in the Stage 1 equalization. The six aeration tanks will be converted to six MBR activated sludge trains, each with internal recycle and return activated sludge pumping. The secondary settling tanks equipment will be removed and the tanks will be used as Stage 2 equalization. The tertiary filter process facility will be demolished as will all other equipment and structures not part of the final plant design. Other improvements include converting existing sludge thickener to waste sludge holding tanks, optimization of the sludge dewatering system and replacement of existing pumps with new, the addition of a dewatered sludge load out building, replacement of the boiler and chiller in the Administration building, replacement of all the concrete pavement, the addition of chemical systems for phosphorus removal and carbon for total nitrogen removal. The existing aeration blowers were rebuilt and reused for scour air and a new process air blower system was added for the activated sludge process. Many of the existing motor control centers are being replaced and the control system is be upgraded for the membrane process.

The plant design was finished and the membrane system was pre-purchased in 2013. Bids have been received and construction began in March 2014. The total project cost is approximately $90,000,000 and less than $3.00 per gallon or wastewater treated. The preliminary treatment facility is expected to be started in March 2015. The MBR activated sludge basins will be constructed one at a time to sequence from old to new technology. The process should be completed and operational in 2017.