PROTECTING THE HEADWATERS OF THE RARITAN RIVER AT THE BOROUGH OF MENDHAM WATER RECLAMATION FACILITY

By Robert C. Fischer, Senior Director, Water Resources, PS&S

The Borough of Mendham Water Reclamation Facility (Mendham) is in Morris County, New Jersey. Early settlers of this historic region predate the Revolutionary War. Historic homes and structures can be found throughout the Borough, including the building which houses Borough Hall, the Pheonix House which dates to 1820. The Borough wastewater treatment plant is located at the bottom of a hill and is situated alongside some pristine waters. The headwaters for the north branch of the Raritan River start here at the India Brook. On any given day of the week, you can find people fly

Figure 1: Borough of Mendham WRF with oxidation ditch and anoxic tank in upper portion of photo.

fishing the brook which runs along the tree lined road leading to the plant. The plant itself is bordered on the south by India Brook, considered a component of the Raritan River headwaters, on the east by a farmer's field and wooded lot, and on the north and west by the wooded acres of the local park system. The plant is staffed by three-(3) recently licensed NJDEP S1 Wastewater Operators. A fourth is scheduled to take the S1 exam and soon the facility will have a full staff of licensed operators with their eyes set on the S2 exam later this year. The Superintendent, Brian Valliere and the operators, like most in the State, are keenly focused on process optimization and this article will describe the operational process changes employed by those operators, with the assistance of PS&S, to improve their effluent nitrate concentrations by approximately 40%, bringing their discharge into compliance with their New Jersey Pollutant Discharge Elimination System (NJPDES) Permit and the steps they plan to take to achieve an additional 20% to 30% improvement.

Mendham is a 0.45 million gallon per day (MGD) secondary wastewater treatment plant. Influent flow from the Borough flows by gravity down the wooded hills to the plant where it is pumped from the main pump house through a pretreatment facility for grit and fine screening removal. Downstream, the flow enters an activated sludge process. The Mendham activated sludge process uses an oxidation ditch, a form of extended aeration, to reduce BOD and ammonia, an anoxic tank to convert ammonia to nitrate and nitrite, mixed liquor return (MLR) pumping to recirculate nitrate laden wastewaters from the oxidation ditch to the anoxic tank for further reduction, and a reaeration tank to aid in the reduction of total dissolved solids. The design is a Modified Ludzack-Ettinger (MLE) process, a modification of a conventional activated sludge process, where the nitrate produced in the oxidation ditch during the ammonia conversion, serves as the source of oxygen for the bacteria in the anoxic tank. Like many small plant oxidation ditches, the looped reactor is larger than necessary, a characteristic that has worked to Mendham's advantage as will be shown. The oxidation ditch uses two horizontal brush aerators (aerators) to mechanically add dissolved oxygen and provide velocity of the mixed liquor flow. The aerators operate on a process control loop which matches the dissolved oxygen (D.O.) in the flow downstream of the

Figure 2: From the left; John O' Brien, Superintendent Brian Valliere, Rafael Jimenez, and Don Ververs, the Operations Staff at Mendham WRF

aerators to a set point on a controller, the rotational speed of the brush aerators increase or decrease to match the controller set point. Within the oxidation ditch, conversion of BOD and ammonia are nearly complete due to the long solids residence time (SRT) or sludge age of the microorganisms. In the anoxic tank, the removal of oxygen from the nitrate ($NO3-$) molecule by facultative heterotrophic bacteria liberates nitrogen which readily combines with other nitrogen molecules to form nitrogen gas, N_2, quickly bubbling out of the system. The anoxic process works well only in the absence of free dissolved oxygen which forces the Nitrobacter bacteria to metabolize biodegradable

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substrate (BOD) using nitrate as an electron acceptor. If dissolved oxygen is available, it will become the oxygen source of choice for these organisms since they require much less energy in consuming free dissolved oxygen than they do in consuming the oxygen from the NO3- molecule. In fact, dissolved oxygen concentrations above 0.3 mg/l in the tank will completely inhibit denitrification from occurring.

Downstream of the activated sludge process at Mendham, aluminum chloride is added at the reaeration tank to aid in phosphorus removal. Flow from the reaeration tank passes through final settling tanks, ultraviolet disinfection, and final discharge. Two lagoons were once used in the process but have since been removed from the process flow. Final discharge is to the India Brook.

The India Brook is classified as FW2, Trout Production, C1 waters and discharge to the Brook brings regulatory limits for TDS of 509 mg/l, ammonia of 3.0 mg/l, nitrate of 15 mg/l, and phosphorous of 1.0 mg/l in addition to the conventional and federal pollutants we are all accustomed to: BOD5, TSS, dissolved oxygen, pH, oil and grease, E. Coli, and toxicity. The Mendham plant, like many oxidation ditch designs, uses a long aeration detention time, 24 hrs., low F:M ratio of 0.05, and a long sludge age of 20 days to consume BOD, grow nitrifying bacteria and convert ammonia. The plant discharges a very clear effluent with BOD and TSS concentrations usually in the low single digits, summertime ammonia < 0.1 mg/l and phosphorous <0.5 mg/l. The same cannot be said for nitrates which averaged 19 mg/l at one point, with spikes as high as 25 mg/l. That is, until the operators embarked on a series of experimental process changes aimed at bringing the effluent nitrate concentrations within permit limit.

TRACING DISSOLVED OXYGEN IN THE PROCESS

To understand the reason behind the poor nitrate removal efficiencies the operators at Mendham began testing different theories. After a series of tests and experiments to rule out low carbon content, inadequate pH levels, temperature and other factors, the operators identified detention time and higher than desirable dissolved oxygen levels being fed to the anoxic tank as the source of their denitrification problems. By tracing the D.O. levels through the process they discovered the mixed liquor return system (MLR) was adding dissolved oxygen to the flow. The MLR system pulls mixed liquor from the bottom of the downstream end of the oxidation ditch and sends it back to the anoxic tank via an intermediary transfer chamber. The transfer chamber is a rectangular concrete vault in which the MLR pumps discharge mixed liquor at an elevation three-(3) feet above the water surface. Operators found this freefall transfer of mixed liquor was adding O2 to the anoxic tank. To correct this problem they rented a temporary, portable diesel pump from Pumping Services Inc, of Middlesex, N.J. to transfer MLR from the oxidation ditch to the anoxic tank in a submerged arrangement eliminating the transfer tank and its free fall effect. This change reduced the effluent nitrate levels from 19 mg/l to 16.8 mg/l. Mendham has subsequently gone to bid on a permanent submerged MLR transfer arrangement, designed by PS&S, to bypass the transfer chamber using the existing pumps and rerouting the discharge piping around the chamber.

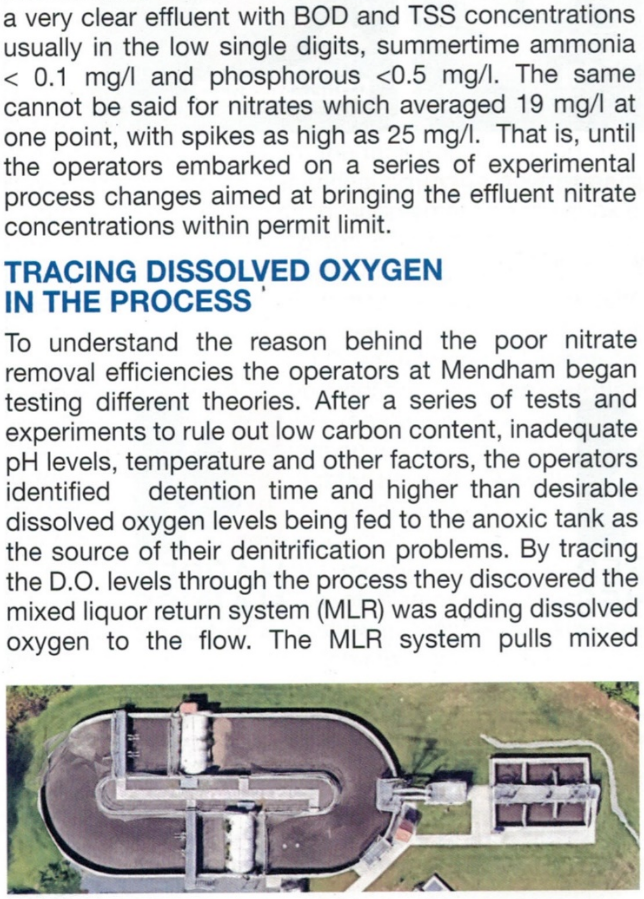

Figure 3: From Left to right, Oxidation ditch, MLR Transfer pumps on downstream side of tank, transfer chamber in center, and Anoxic Tank on right.

DETENTION TIME AND CREATING AN ANOXIC ZONE IN THE OXIDATION DITCH

The reduction to 16.8 mg/l was a good outcome but did not achieve compliance with the 15 mg/l limit, so the operators next focused their efforts on detention time. They assumed the anoxic tank with a 2-hour detention time would be enough to drive the conversion of NO3- to N2 but it was not. Dissolved oxygen levels at the influent of the tank were still measuring 0.2 mg/l., as carryover from the oxidation ditch. After the 2-hour detention time in the anoxic tank the levels were under 0.1 but not until the exit of the tank, levels 2/3rd of the way through the tank still measured 0.2 mg/l. The size of the anoxic zone affects the degree to which nitrate reduction can proceed and the size of the tank did not provide enough detention time to dissipate the 0.2 mg/l D.O. tank influent concentration. The operators decided that denitrifying in the downstream end of the oxidation ditch would be necessary to reduce the D.O further before it enters the anoxic tank. As mentioned earlier, the Mendham oxidation ditch is larger than necessary for conversion of BOD and ammonia. By using the downstream, effluent portion of the tank to begin the anoxic denitrification process, Mendham essentially created an anoxic zone in the oxidation ditch, leaving the influent end of the oxidation ditch for

Figure 4: MLR bypass pump provided by Pumping Services with orange suction line adjacent to MLR pumps, and yellow discharge line leading to anoxic tank on left.

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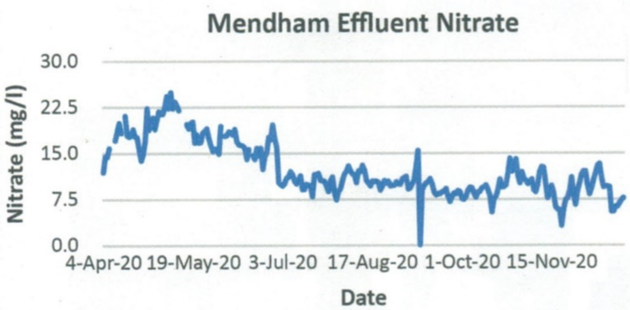
aerobic conversion of BOD and ammonia. They also implemented a high – low alternation of the dissolved oxygen set point, where for part of the day the D.O. set point was set very low, followed by the remainder of the day at a higher set point. This alternation is like the on-off operational strategy employed by others in the industry.

HIGH – LOW ALTERNATION OF DISSOLVED OXYGEN

The high period of the day was defined by adjusting the set point on the upstream aerator to 1.1 mg/l and setting the downstream aerator on a manual setting at minimal speed. The low period of the day was defined by adjusting the set point on the upstream aerator to 0.6 mg/l leaving the downstream setting at minimal speed. The high period was set from 3 pm to 6 am and the low period from 6 am to 3 pm. This adjustment



produced good results and the D.O. in the bottom of the downstream portion of the tank began to drop. The lower D.O. produced denitrification in the downstream portion of the oxidation ditch, supplementing the anoxic tank and bringing the plant effluent nitrates down to a consistent range of 8 to 11 mg/l, a safer zone of operation from a permit limit standpoint. Unfortunately, it also created the growth of filamentous bacteria. As a consequence of the lower D.O. adjustments, filamentous foam began to build on the oxidation ditch tank surface and began migrating to the reaeration tank where the operators removed the foam on a daily basis. The solids settling was impacted slightly as well. Resetting the system back to normal operational conditions reduced the foam but once again increased the nitrates. They found that operating in this regime is a balancing act between acceptable levels of filamentous foam and nitrates. The process adjustments continued, and the latest operational process change was switching the high-low periods of the day, where the lower D.O. is maintained from 11 pm to 6 am, and the higher D.O. is maintained from 6 am to 11 pm. Finally, with this change, the filamentous foam has all but disappeared, settling is back to normal and the nitrate levels are within a safe, albeit slightly higher range of 9 to 12 mg/l. PS&S and the Operators know they can do more and are planning the next phase.

The next phase of this stepwise nitrate reduction process is the institution of additional process control capabilities. Mendham has a SCADA and process control system, yet it cannot preset brush aerator D.O. concentrations by time increments which would allow the aerators to be adjusted on and off several times per day. On-Off operation of oxidation ditches is not a new concept. It is usually coupled with mixers to keep the mixed liquor circulating within the oxidation ditch when the brush aerators are off but can, in the case of Mendham, work well to bring the nitrate levels to the desired 3 to 6 mg/l range.

The old saying *"nothing succeeds like failure"* is so true in this story. Since embarking on the cure for the high nitrate levels there have been many failed attempts to find the cure. Each failure though, brought with it a bit more valuable information. At this point, the operators are no longer worried about compliance, they have learned a great deal about their process and are committed to running the system at its greatest potential, which will only lead to greater understanding. Like most licensed operators in the State of New Jersey, the Mendham Operators are dedicated to protecting the receiving waters, in this case the headwaters of the Raritan River.

PS&S is the Engineer of Record for the Borough of Mendham and in early 2020 became their temporary licensed operator of record. PS&S has designed upgrades to the water reclamation facility which will improve the pretreatment, main pumping and oxidation ditch processes. Those designs will go to bid toward the later part of 2021.

CLOSING NOTE:

Readington Lebanon Sewerage Authority Administrator, and NJWEA President Elect, Jill Plesnarski visited the Mendham WRF in April of this year and invited the Mendham staff to tour the Readington Lebanon facility a few weeks later. These kinds of exchanges are always beneficial to the operators. Jill has a strong analytical and laboratory background and during the visits to Mendham she retrained the staff on the use of the Winkler method for measuring Dissolved Oxygen and reviewed their techniques for TDS and TSS. During the visit to the Readington Plant Jill discussed the facility operating processes which are similar in many ways to the Mendham plant. Staff spent a couple of days sharing experiences, laboratory techniques and discussing nitrogen removal strategies.

Figure 6: Jill Plesnarski, President Elect of NJWEA and Administrator of Readington Lebanon Sewerage Authority provides laboratory instruction to the Mendham Operators.