Tertiary wastewater treatment through MBBR technology

Student Team: Ethan Ackerman, Grant Harris, Gregory Jensen, Christopher Ruben, Stephen Sadler

Industry Sponsor: WesTech Engineering; Industry Mentors: Kirsten Sims; Faculty Advisor: Ronald C. Sims

Abstract
Wastewater treatment is an essential component to public health as it removes harmful compounds and allows for water reuse and recycle. Biological nutrient removal has entered into the public spotlight as efficient flows with high nitrogen concentrations have detrimental effects on water discharge bodies. Traditional suspended growth biological treatment methods are expensive and produce excess biomass that can reduce the efficiency of nutrient removal if not maintained. Research on the benefits of attached growth processes, namely moving bed biofilm reactor (MBBR) technology, presents an exciting innovation in wastewater treatment that can increase nutrient removal efficiency and reduce overall cost.

As the Logan Wastewater Treatment Plant aims to implement a $150 million project to account for nutrient removal, the MBBR system and its benefits should be considered as a potential solution. The aim of this project was to determine the necessary parameters for a tertiary, nitifying MBBR system for the Logan Wastewater Treatment Plant and to operate a pilot-scale MBBR system. Design considerations included the Logan Plant’s maximum hourly flow rate, seasonal fluctuations in water temperature, ammonia concentration, and dissolved oxygen concentration.

Water was determined to be the critical reason for the design, as the winter parameters resulted in a larger reactor volume, increased aeration requirement, and a longer hydraulic retention time compared to summer months. This was attributed to the lower kinetic rate of nitrification and increased ammonium concentration in colder climates.

Introduction
Tertiary water treatment is the final cleaning process in wastewater treatment that improves the water quality before being reused, recycled, or discharged. This process involves the removal of many inorganic compounds, but the removal of nitrogenous chemicals is particularly important. High nitrogen content in water can lead to problems such as eutrophication in public water sources if left untreated. Nitrogen removal is accomplished by utilizing bacteria in the process of nitrification, where ammonium is oxidized to nitrate, and denitrification, where nitrate is reduced to nitrogen gas.

Methodology
Research necessary design parameters for wastewater treatment
Collect seasonal data for temperature, dissolved oxygen, and ammonium concentration in lagoon effluent stream
Develop a CAD model of the proposed design

Design Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent TAN (mg/L)</td>
<td>20</td>
<td>5.75</td>
</tr>
<tr>
<td>Effluent TAN (mg/L)</td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td>Influent DO (mg/L)</td>
<td>9.6</td>
<td>6.8</td>
</tr>
<tr>
<td>Influent Temperature (°C)</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Max Oxygen Solubility (mg/L)</td>
<td>15.3</td>
<td>17.5</td>
</tr>
<tr>
<td>Daily Flow Rate (mgd)</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Max Hourly Flow Rate (mgh)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Ammonium Removal Rate (mg/L/hr)</td>
<td>4.58</td>
<td>10.83</td>
</tr>
</tbody>
</table>

Conclusion
- Tertiary treatment of the Logan lagoon effluent is feasible with incorporation of a moving bed biofilm reactor.
- Due to the significant increase in ammonium concentration in the winter months, a greater aircap rate is needed in the winter months than summer months for tertiary ammonium removal.
- Aeration requirements contribute the most to the yearly operational costs of the MBBR system.
- Slower kinetic rates, due to cold water temperatures during the winter months, contributed significantly to the hydraulic retention time. The high hydraulic retention time during winter was the greatest contributor to the overall reactor dimensions, volume, and aeration requirements.
- MBBR advantages, such as shorter HRT, longer SRT, low-temperature nitrification, and smaller reactor volume provide a more efficient design than traditional suspended growth systems.

Project Challenges
- Legal disputes between the two industry sponsors over proprietary information led to four separate iterations of the design project:
  1. Determine kinetic models of a novel encapsulated cell technology for nitrogen removal from wastewater (February 2018 to June 2018).
  2. Design a continuous flow reactor for ammonium removal with the novel encapsulated cell technology (June 2018 to September 2018).
  3. Collect and analyze ammonium removal rates from the novel encapsulated cell technology. WesTech Engineering provided a pilot-scale reactor for this purpose (September 2018 to November 2018).
  4. Develop a paper design of an MBBR tertiary water treatment reactor for incorporation in the Logan, Utah wastewater treatment system (November 2018 to current).

For iterations three and four, mechanical failures of the provided pilot-scale reactor precluded the opportunity to collect ammonium removal rates from the encapsulated cell technology and MBBR media.

Based on an estimated start up time for MBBR media of four weeks, there was insufficient time for data to be collected and analyzed for iteration four.

Acknowledgements
We would like to extend special thanks to:
- Kirsten Sims: main industry contact and liaison between Micravi and the design team.
- Mark Bissinger: provided extensive guidance on the development of the final MBBR design.
- Tyler Ayers: primary industry contact in Logan, Utah. Liaison between WesTech Engineering and design team.
- Jacob Welch: building and delivery and the provided reactor.
- Ronald C. Sims: provided guidance on industry relations and expertise throughout the design process.
- Tim Lindley: main contact at the Logan lagoons and provided extensive assistance for characterizing the lagoon effluent.

References
2. To study the performance of biofilters in moving bed biofilm reactor (MBBR) technology and kinetics of biofilms for retrofitting the existing aerobic treatment systems: a review , 2014.
3. City of Logan Wastewater Treatment Master Plan, 2015.