Background

The Abbott Nutrition facility in Sturgis, Michigan produces a large variety of products in batch processes. An onsite industrial pretreatment plant (IPP) treats wastewater generated from clean-in-place procedures, and other plant processes, before discharging to a municipal wastewater treatment facility. System flow and areas of improvement shown in Figure 1.

Three main issues are occurring in the wet well:

- Undesired anaerobic fermentation and production of volatile fatty acids (VFA)
- Decreases the pH of the system
- 30-40% of the pump station volume does not turn over during a normal cycle (N. Hough, personal communication, October 2, 2020).
- As a result, microbes produce malodorous and corrosive hydrogen sulfide (H2S).
- The hydrogen sulfide threatens the integrity of the system and affects the surrounding environment
- Wet wells have previously experienced major erosion (C. Gilbert, personal communication, November 20, 2020)

Design Alternatives

Three design alternatives were developed to combat the VFA and H2S production. These designs are distinguished by a change to the inputs of the system, a modification of the system itself, or an alteration of the output of the system.

1. Baffles/pump extension
   • The baffles and pump extension will be a modification to the system itself. This design is the addition of components to the wet well.
   • This is a cost-effective design that extends the current wet well pumps to the maximal allowable depth and adds baffles into the basin.
   • Fermentation and VFA build up are addressed by decreasing retention time and increasing the flow out of the wet wells. The wastewater pH is then closer to neutral and therefore less costly to treat in the equalization tanks. The increased flow velocities caused by the baffles reduces H2S production by disrupting the solids build up in the well and allowing the newly extended pumps to perform without vortex formation and cavitation.

2. Reverse Osmosis (RO) System
   • This design reduces biological H2S production (described by Equations 1 and 2) by reducing the sulfate load going to the IPP.

   Conversion of sulfide to hydrogen sulfide gas (Metcalf & Eddy, 2014)

   Organic matter + SO4− + bacteria → S2− + H2O + CO2
   (1)

   S2− + 2H+ → H2S
   (2)

   • Approximately 65% of the IPP’s sulfate load is coming from the plant’s boiler water ion exchange pretreatment unit. Switching from ion exchange to reverse osmosis for boiler feedwater treatment will eliminate a high strength sulfate stream going to the IPP, which will decrease H2S production.

3. Pump replacements
   • The 4 wet well pump replacements will address the anerobic fermentation and VFA accumulation. Gould’s Vertical Industrial Turbine (VIT) Pump is optimal for the system based on Abbott’s standards and regulations for new pumps in the wet wells (Gould’s Pumps, personal communication, February 25, 2021).
   • The pump recommendation for the equalization basin is self-priming. Vaughan’s E Series 3-6 in Vertical Recirculator Chopper Pump would meet Abbott’s needs in the equalization basin (J. Niels, personal communication, February 28, 2021).
   • This alternative was ultimately eliminated due to its high initial cost ($178,900), which results in an estimated payback period of 27.5 years.

Selected Design

The selected design is a combination of two designs - the baffles/pump extension and the RO system. The combination of these designs will successfully improve Abbott’s IPP system and meet the client’s payback period constraint.

1. Baffles/pump extension details
   • The pump is lowered by extending the pumping shaft by 1.6 ft, illustrated in Figure 3
   • The baffle will be made of stainless steel 304 due to its microbial resistant properties. This stainless-steel baffle will be attached to a stainless-steel coated concrete box beam that sits above the high-water level in the well (~12 ft). The coating will be ¾ in thick. The dimensions of the baffle are 10 in x 24 in x 4 in, and the box beam dimensions are 372 in x 4 in x 4 in. Placement is shown in Figure 4.
   • There are 4 wet well pumps that will receive the extension. Implementation of the extension will occur on one pump per year over during Abbott’s two-week annual shutdown. The baffles will be installed during the first year of implementation. This design will take 4 years to fully implement.

Economics & Conclusion

The economic evaluation considers total costs including installation, added maintenance, and operation. The annual savings from the design were then used to calculate the simple payback period for the designs. Abbott’s constraint for the payback period is 2.5 years. Each design was considered separately for the economic analysis. Table 1 presents a comparison of the costs of the recommended designs.

<table>
<thead>
<tr>
<th>Design</th>
<th>Total Initial Cost</th>
<th>Net Annual Savings</th>
<th>Payback Period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO Unit</td>
<td>$60,000</td>
<td>$36,100*</td>
<td>1.7</td>
</tr>
<tr>
<td>Baffle Placement and Pump Extension</td>
<td>$14,404</td>
<td>$6,600*</td>
<td>2.2</td>
</tr>
</tbody>
</table>

*Based on a conservative 5% reduction in caustic use

The team recommends that Abbott Nutrition implement both the baffles and pump extension design and the RO system. The baffles will increase flow velocities in the wet well, and the pump extensions will decrease the retention time from 4 days to 0.985 days. These improvements meet the project objectives by promoting aerobic conditions in the wet well, reducing solids production, RO production, and consequently decreasing caustic chemical costs. An extremely conservative estimated payback period of this design is 2.2 years, which is under Abbott’s 2.5-year payback period constraint. Concurrently with the baffle and pump extension design, the team recommends that Abbott Nutrition replace their ion exchange-system with a RO system for treating boiler feed water. This will reduce the sulfate loading to the IPP by approximately 65%, which will reduce H2S production in the wet well. This design has an estimated payback period of 1.7 years, which is also within Abbott’s constraint. The IPP site is depicted in Figure 6.

References
