Tertiary wastewater treatment through MBBR technology

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Abstract

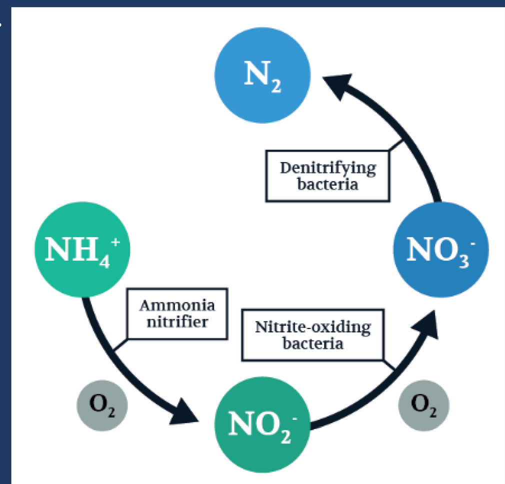
Wastewater treatment is an essential component to public health as it removes harmful compounds and allows for water reuse and recycle. Biological nutrient removal has entered into the public spotlight as effluent flows with high nitrogen concentrations have detrimental effects on water discharge bodies. 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, nitrifying 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, ammonium concentration, and dissolved oxygen concentration.

Winter was determined to be the critical season 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 slower 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 methemoglobinemia in infants and eutrophication in public water sources if left untreated. Nitrogen removal is accomplished by utilizing bacteria in the processes of nitrification, where ammonium is oxidized to nitrate, and denitrification, where nitrate is reduced to harmless nitrogen gas[1].



Reaction route of conventional nitrification and denitrification

Traditional suspended growth systems for nitrogen removal require costly clarifiers as nitrification increases bacterial biomass, which must be removed before water reentry into the ecosystem[1]. The MBBR technology employs polymeric carriers as a surface for bacterial adhesion. The high surface area of the carriers allow for higher concentrations of active bacterial populations, which shortens the necessary treatment time when compared to suspended growth systems. MBBR technology is also capable of self-sustaining optimum levels of productive bacterial populations which limits biomass production and the need for expensive clarifiers[2].

The current wastewater treatment plant in Logan, Utah does not contain a tertiary nutrient removal system. Implementation of a tertiary MBBR process would facilitate efficient nitrogen removal for the growing population of the city, while meeting future city standards.

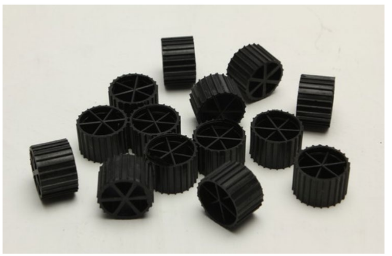
Methodology

Research necessary design parameters for wastewater treatment


DO Probe

Collect seasonal data for temperature, dissolved oxygen, and ammonium concentration in lagoon effluent stream

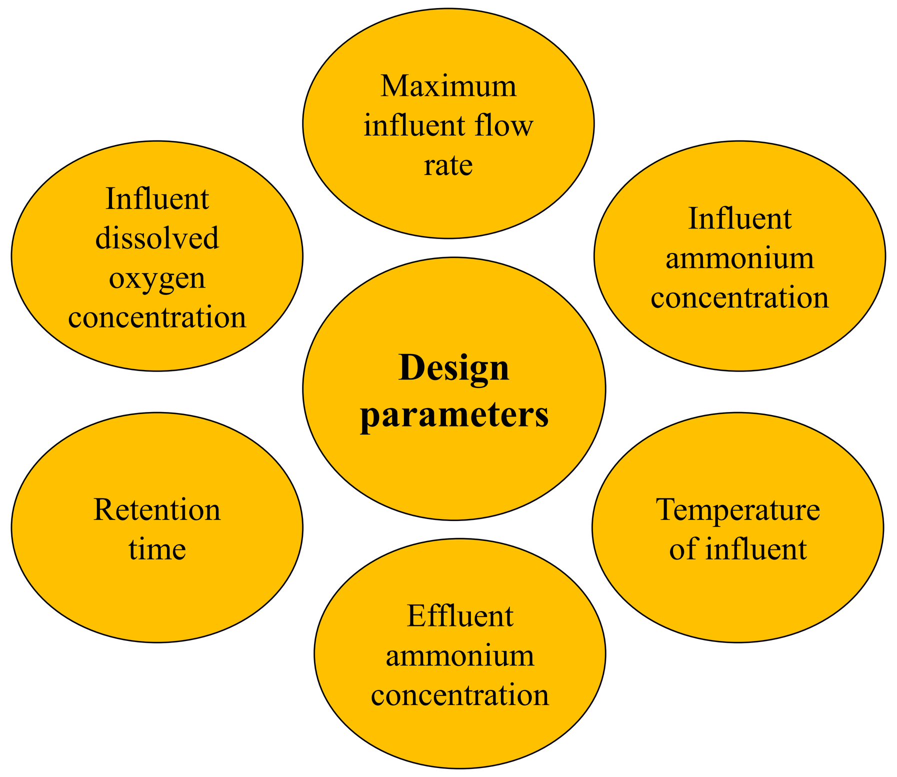
Calculate parameters for tertiary MBBR system at Logan Wastewater Treatment Plant


Polymeric Microcarriers

SOLIDWORKS

Develop a CAD model of the proposed design

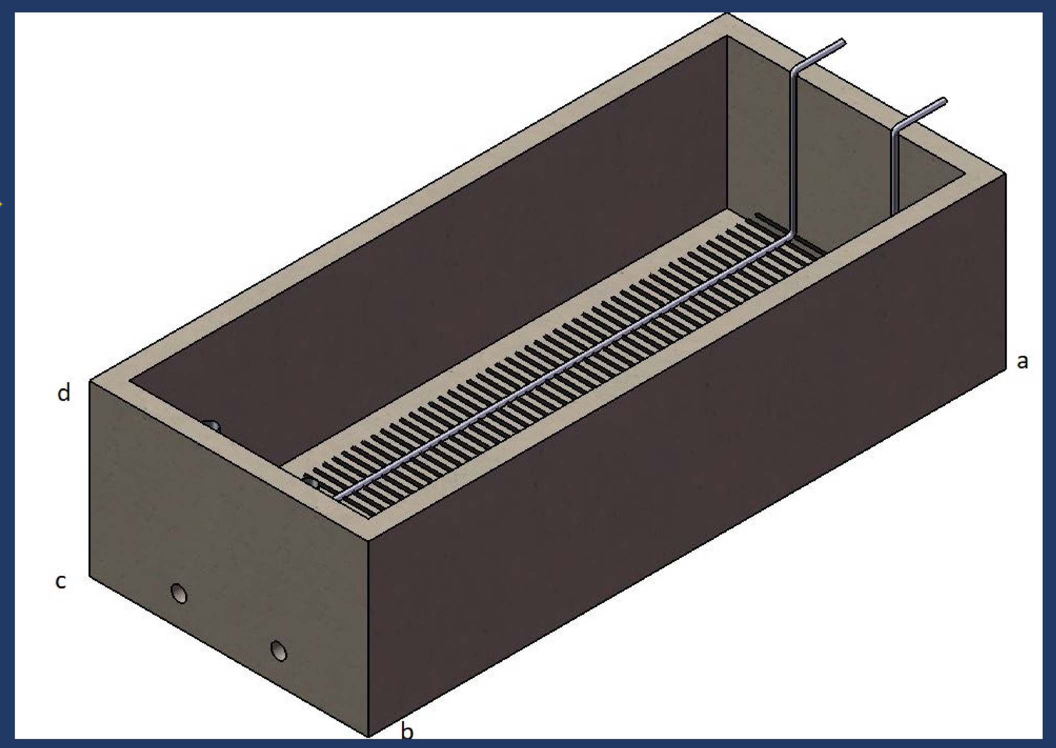
Design Parameters



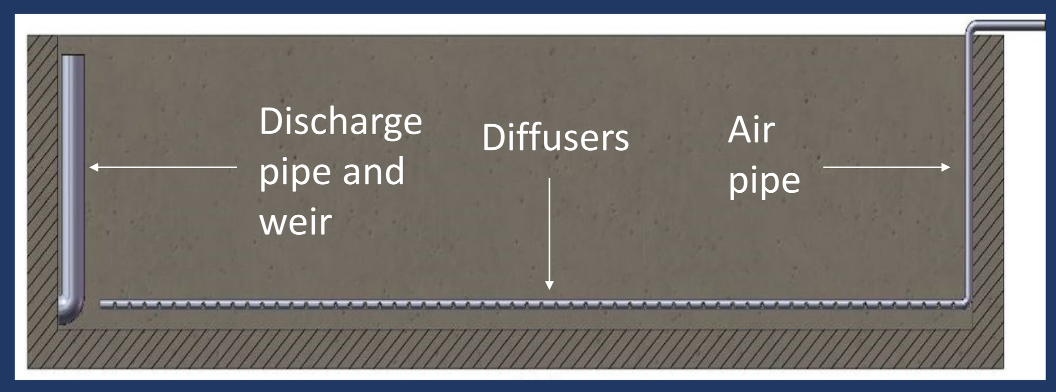
Results

WASTEWATER CHARACTERISTICS[3]	Winter	Summer
Influent TAN (mg/L)	20	5.75
Effluent TAN (mg/L)	3	1.3
Influent DO (mg/L)	9	6.6
Influent Temperature (°C)	1	20
Max Oxygen Solubility (mg/L)	12.3	7.5
Daily Flow Rate (mgd)	36	36
Max Hourly Flow Rate (mgh)	5	5
Ammonium Removal Rate (mg/L*hr)	4.58	10.83

DESIGN PARAMETERS	Winter	Summer
Ammonium effluent limit (mg/L)	3	1.3
Reactor Volume (10^6 L)	117	31.6
Reactor Depth (ft)	15	15
Reactor Width (ft)	251	251
Reactor Length (ft)	1,004	261
HRT (hours)	3.7	1
Air Flow (CFM)	45,500	13,100
Fill ratio (%)	60	60
Specific Surface Area (m^2/m^3)	800	800
Diffuser Power Requirement (kW)	226	19
Number of Diffusers	2,438	539
Compressor Power Requirements (kW)	2,237	



Isometric view of potential MBBR design: 1004 feet (a-b), 251 feet (b-c), 15 feet (c-d)



Sectional view of potential MBBR design

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 air flow 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 reactor.
- 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[4], there was not sufficient time for data to be collected and analyzed for iteration four.

Acknowledgements

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- Jacob Welch: building and delivery and the provided reactor.
- Ronald C. Sims: provided guidance on industry relations and expertise throughout the design process.
- Tim Lindsay: main contact at the Logan lagoons and provided extensive assistance for characterizing the lagoon effluent.

References

1. Wastewater Engineering: Treatment and Reuse, 2003.

2. To study the performance of biocarriers in moving bed biofilm reactor (MBBR) technology and kinetics of biofilm for retrofitting the existing aerobic treatment systems: a review , 2014.

3. City of Logan Wastewater Treatment Master Plan, 2015.

4. Influence of High Organic Loading Rates on COD Removal and Sludge Production in MBBR Reactor, 2007.