Department of Biosystems and Agricultural Engineering
MICHIGAN STATE UNIVERSITY

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Biosystems Design Projects

Feasibility Study of Greywater Reuse for Dairy Plant CIPs (Under NDA)

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Client: Glanbia Faculty Advisor: Dr. Wei Liao, PE

Glanbia

Background[1]

Glanbia is a multinational milk processing company. The plant in St. Johns, MI is their largest and newest in the United States. Annually, the St. Johns plant processes 2.9 billion lb of milk to produce 300 million lb of cheese and 20 million lb of whey protein. As a result, they produce around 548 – 657 million gal of wastewater every year. Glanbia is looking to save production cost by reusing some of their wastewater for clean in place purposes.

Problem Statement

Assess the feasibility of utilizing recycled and treated wastewater as a substitute for the city water supply in clean in place (CIP) processes at a dairy production plant.

Literature[2]

Several sources have reported success in repurposing treated wastewater as an additional water supply. Researchers in the Lipid Science and Technology Division from the Indian Institute of Chemical Technology tested a system using a combination of coagulants and a series of filtration systems to reuse wastewater produced from the local dairy industry. They concluded that the result was comparable to city water quality.

Objectives

- Develop a design that will recycle 20% of Glanbia's discharge volume back to the production facility
- Extend the operational lifespan of the ultrafiltration membrane filters in the membrane train by 50%
- Reduce municipal water usage by 100%
- Clean wastewater to standards specified by the Food and Drug Administration (FDA) in the 2024 Pasteurized Milk Ordinance (PMO)

Constraints

Per our client, John Davies, the proposed solutions must meet the following requirements and regulations:

- Footprint of 42' x 53' (2226 ft^2)
- No height restriction
- FDA (PMO, Appendix D, PMO, Part II, Section 7)
  - Governs water reuse in a dairy plant
  - Categorizes reclaimed water by its intended use
- EPA – National Primary Drinking Water Regulations
  - Governs drinking water standards for water systems
  - Outlines contaminant limits for microorganisms and inorganic chemicals

Design Alternatives

Two treatment solutions will be used to target the needs of Glanbia's wastewater treatment plant (WWTP). The design solution was split into 2 stages to better target the team's objectives. Stage 2 was the primary focus, with Stage 1 serving as an additional treatment.

Goals for stage 1:

- Located between aeration basin and membrane train
- Improved settling
- Removal of solids from wastewater stream
- Extend the life-span of subsequent filters

Design alternatives for stage 1:

- Settling Tank
- Centrifuge
- Inclined Plate Clarifier (IPC)

Goals for stage 2:

- Located at the end of Glanbia's current WWTP
- Further purification of effluent to city water/ regulated standards
- Treatment of pathogens and contaminants

Design alternatives for stage 2:

- Reverse Osmosis (RO)
- Reroute
- Ultrafiltration
- Nanofiltration

A schematic of where the stages are in Glanbia's WWTP is shown in Figure 1. The black items are current processes in Glanbia's WWTP and red items are additional stages the team plans to add.

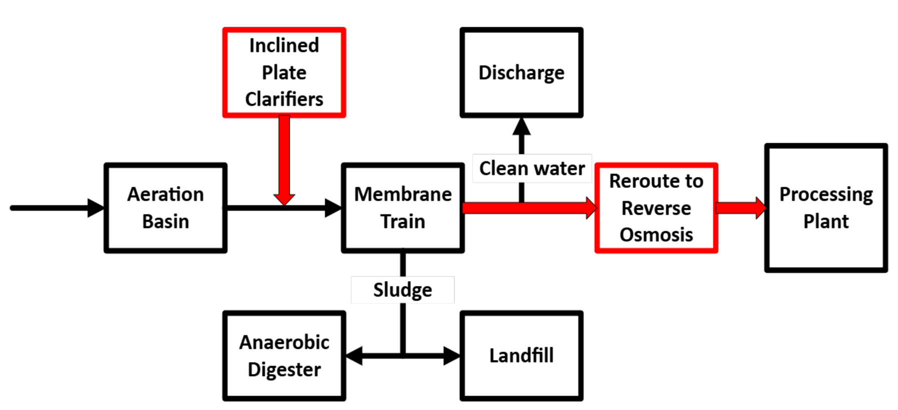

Figure 1. Treatment flowchart schematic

Figure 2 showcases the layout of Glanbia's current WWTP, the location of treatment 2, and the treatment footprint constraint.

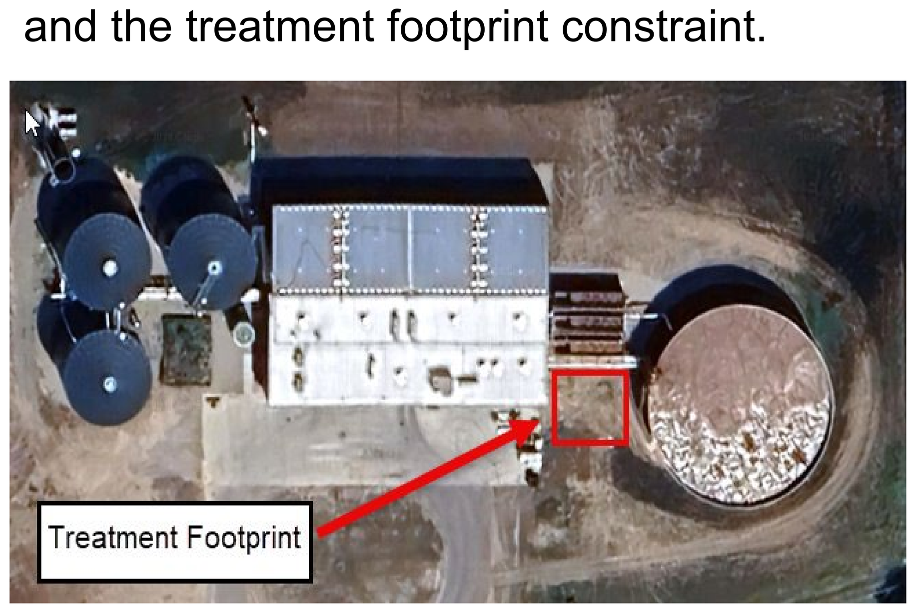

Figure 2. Satellite view of Glanbia's WWTP

Selected Design[3]

Proposed Solution (Stage 1):

Inclined Plate Clarifier

- M.W. Watermark SPC-300 shown in Figure 3
- 5 units used in parallel
- 31' x 35' (1,085 ft^2) footprint required
- Sludge routed to belt press
  - Used as feedstock for anerobic digestion

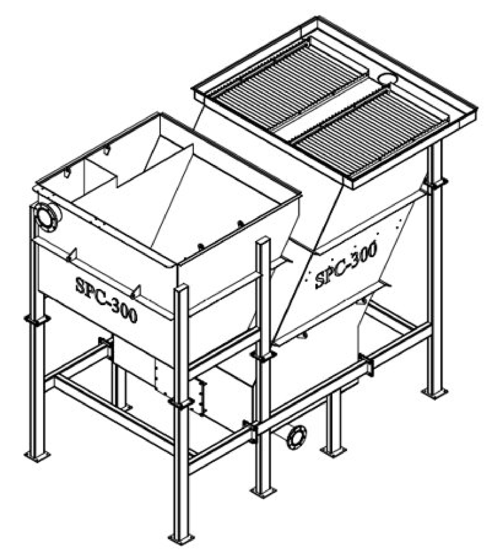

Figure 3. Technical drawing of the SPC-300

Proposed Solution (Stage 2):

Reroute to existing RO system. Piping plan is shown in Figure 4

- Recycled water must meet standards and regulations
- Able to remove all organic compounds, pathogens, and most minerals
- Required piping is 0.25 miles long

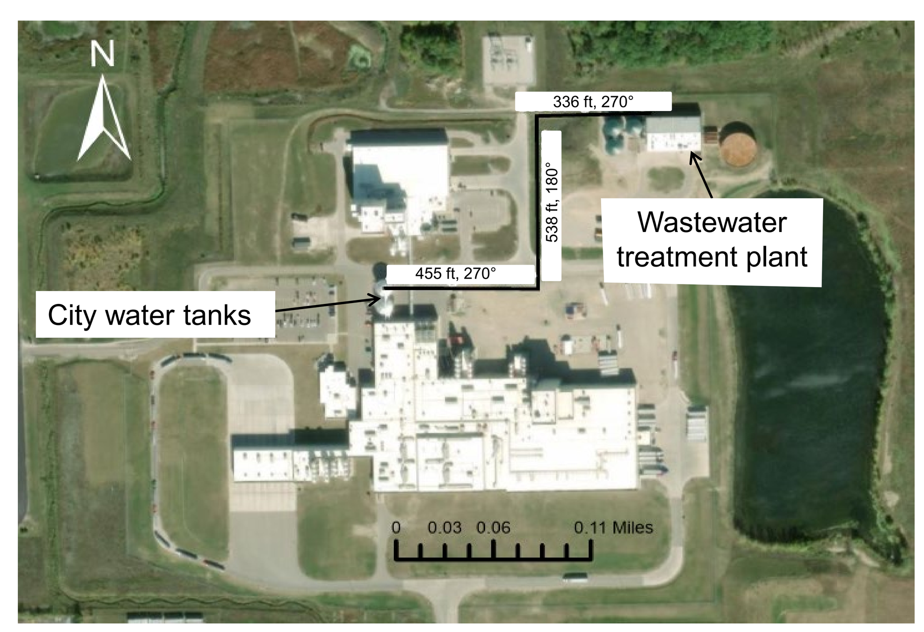

Figure 4. Proposed reroute plan

Pilot Testing

The team conducted pilot testing over the span of two business weeks. A small-scale RO unit was used to confirm viability of using RO to improve water quality. The unit used can be seen in Figure 5.

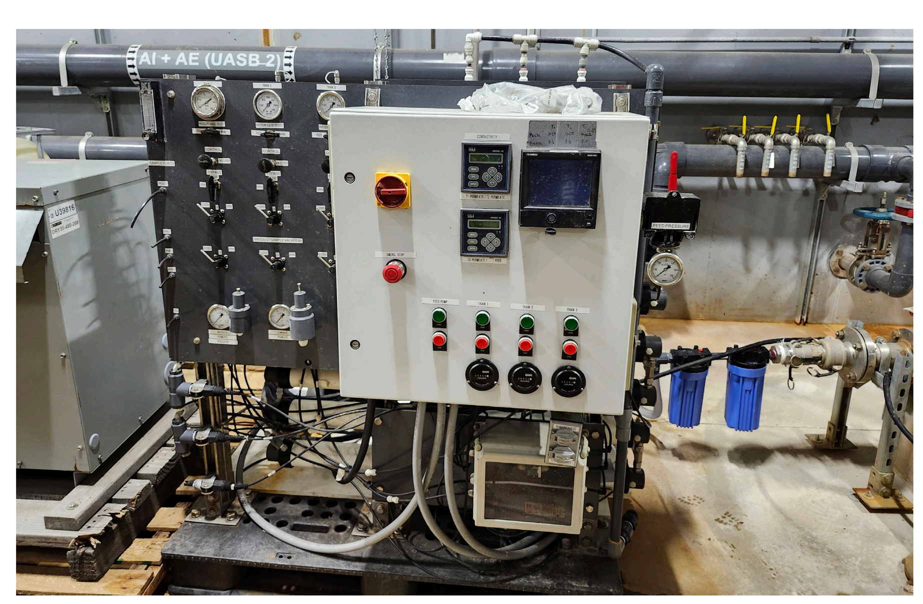

Figure 5. Small-scale single stage RO unit

Pilot Testing cont.

During the pilot testing period, influent and effluent samples were collected. The team conducted testing on the samples, which included:

- *E. coli*
- Total coliform
- TSS
- pH
- Conductivity
- Chemical Oxygen Demand (COD)

A result of the *E. coli* and total coliform testing can be seen in Figure 6.

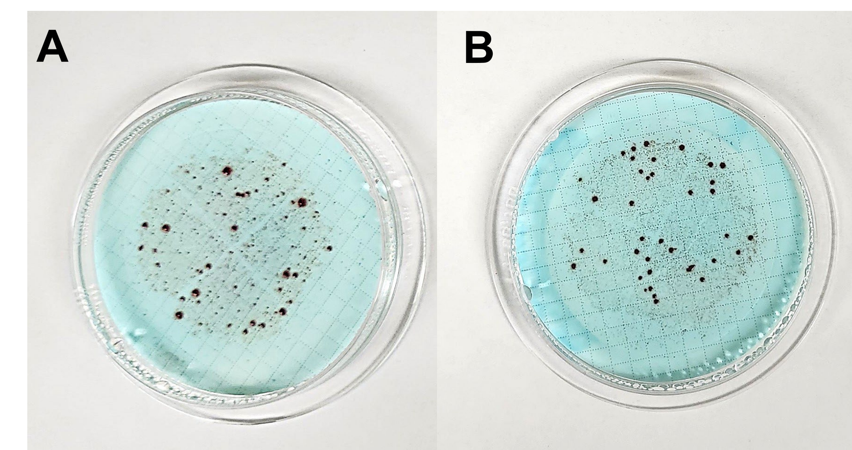

Figure 6. Petri dishes from total coliform and *E. coli* testing. **A)** result from influent flow to the RO. **B)** result from effluent flow from the RO.

Figure 6 shows a significant reduction in coliform bacteria after the wastewater stream is treated using the RO unit. More testing results are shown in Table 1.

Table 1. Results of pilot testing

Parameter	Influent	Effluent
E. coli	2.00±3.94	0±0
Total coliform	213.8±81.0	117.1±114.9
TSS	0.0736±0.0007	0.0755±0.0057
pH	7.20±0.35	7.15±0.30
Conductivity	3.19±0.01	3.19±0.2
COD	329.75±111.37	178.46±175.70

The data in Table 1 was used to calculate the percent change between the influent and effluent. The results are shown in Table 2. Green cells are good results, while red cells weren't positively affected.

Table 2. Percent change of parameters

Parameter	% Change
E. coli	-100.00
Total coliform	-45.00
TSS	2.58
pH	-0.69
Conductivity	0.00
COD	-46.00

The results showed that the pilot test can:

- Completely remove *E. coli* from the wastewater
- Significantly reduce total coliform and COD
- Maintain pH level of the wastewater

The pilot test was not able to:

- Completely remove total coliform
- Reduce TSS or conductivity

Despite the negative values, RO is still viable. Milk processing facilities more commonly use a multistage RO to filter water, instead of a single stage RO like what was used in testing

Economics[4]

The team conducted an IRR calculation to analyze the economic performance of this solution.

- Stage 1 capital cost came from a quote from M.W. Watermark
- Stage 2 capital cost came from a combination of piping costs from a quote and literature data from Thomas et al.
- Linear approximation of literature data to adjust for flowrate

Figure 7 shows the breakdown of the total capital cost of implementing both stages of the proposed treatment plan.

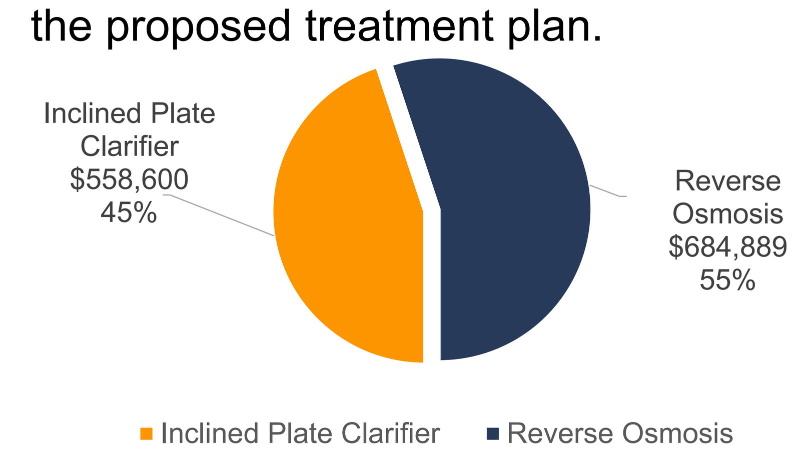

Figure 7. Capital Cost of each stage

A lifetime of 20 years was used for the IRR analysis. Savings was used for revenue as Glanbia would be saving cost instead of generating revenue with this project. The result of the IRR calculation is shown in Table 3.

Table 3. IRR of the proposed project

Initial Rate of Return	
Investment ($)	1,243,489
Savings ($/year)	1,400,000
Lifetime (year)	20
IRR	**113%**

The project is economically beneficial with an IRR of 113%. Additionally, there are low interest loans such as the Clean Water State Revolving Fund by the EPA to fund the project.

Conclusion

Using RO, it is feasible to recycle 20% of Glanbia's discharge volume at this plant, eliminating 100% of municipal water use. Implementation of IPCs would benefit all other parts of WWTP.

Acknowledgements

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Select References

1. Cheese & Whey Protein Manufacturing Facility Michigan. MWC. (2023, August 4). https://mwcmichigan.com/our-business/
2. Sarkar, B., Chakrabarti, P. P., Vijaykumar, A., & Kale, V. (2006). Wastewater treatment in dairy industries — possibility of reuse. *Desalination*, *195*(1–3), 141–152. https://doi.org/10.1016/j.desal.2005.11.015
3. *Slant Plate Clarifier: M.W. Watermark*. MW Watermark Wastewater Treatment Manufacturer. (n.d.). https://mwwatermark.com/products/slant-plate-clarifier/
4. Thomas, B. D., Marks, A., Smerigan, B., Aburto-Vazquez, G., Uludag-Demirer, S., Dusenbury, J. S., & Liao, W. (2024). Life cycle impact and economic assessment of decentralized strategies to treat source-separated wastewater. *Journal of Water Process Engineering*, *64*, 105550. https://doi.org/10.1016/j.jwpe.2024.105550