

# Automation of COD and TOC Monitoring for Pharmaceutical Waste Streams

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Client: Perrigo

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## Background

Wastewater treatment is a necessary step for manufacturing facilities that removes contaminants or residual products from the waste fluid before it exits to the public sewage system, recycled back into the industry, or flow to an outside water source. Our team is working with Perrigo, a large producer of generic over the counter pharmaceutical products founded and located in Allegan, MI. Their current manual diversion system, shown in Figure 1, leads to occasional unknown spills of leaking product into wastewater treatment plants. Figure 2 shows the diversion piping that takes the wastewater to the treatment plants, or the waste tank. This has been the cause of multiple fines from the city treatment plant, as well as costs to replace their treatment equipment. With each occurrence, not only do they receive fines, but it also leads to large costs in equipment damage and product loss. We are working with them on their liquid fill plant (fill line shown in Figure 3) to prevent leakage of their product into their waste line and out into Allegan's city water treatment plant.

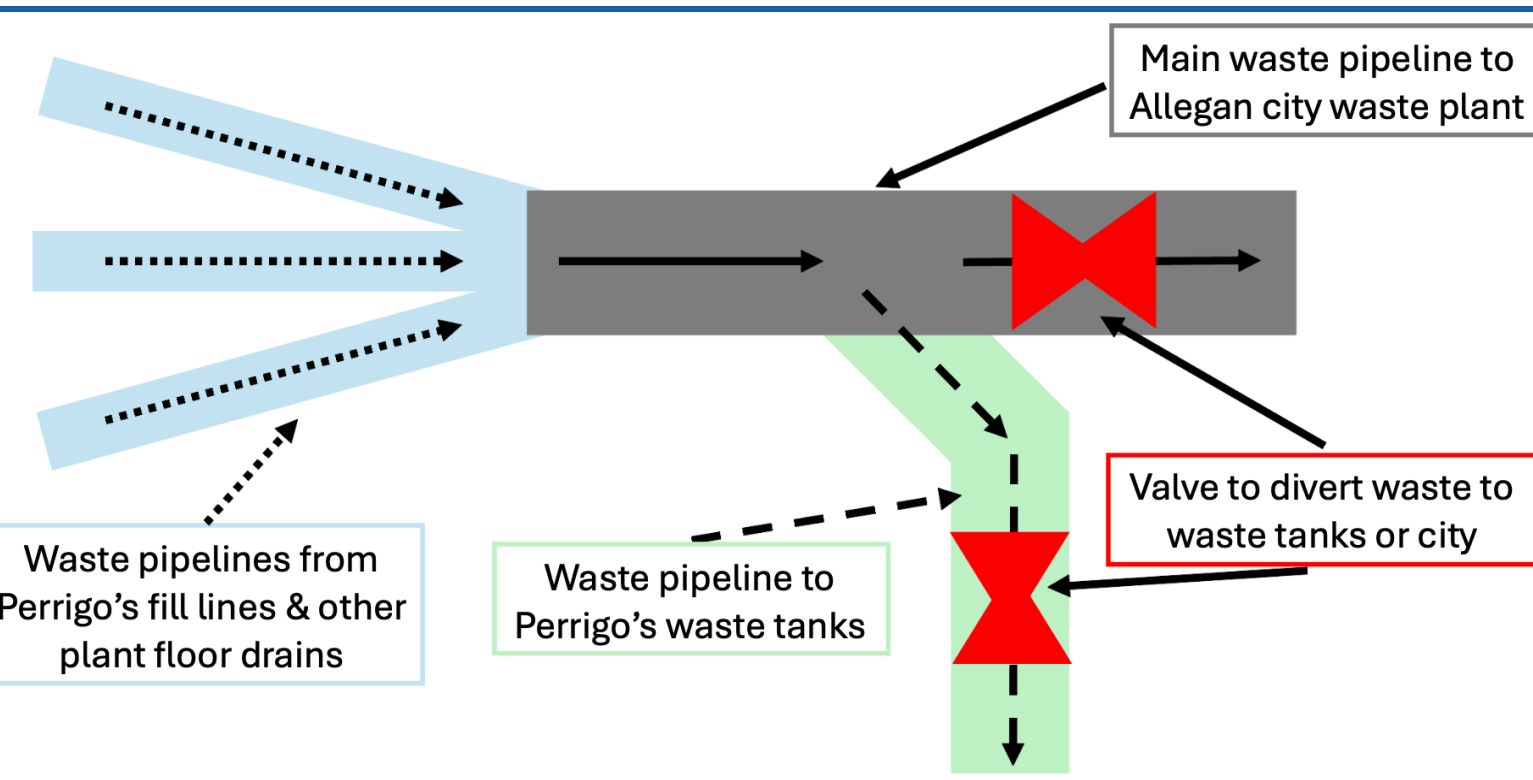


Figure 1. Diagram following wastewater path from waste lines to main pipe then diversion if necessary.



Figure 2. Main wastewater pipeline Y-split.

Figure 3. Liquid product fill line station drain (T. Grybus, personal communication October 29, 2025).

## Problem Statement

Investigate a technology – driven solution capable of detecting the presence of product in a waste line based on concentration. Then, design a solution to automatically divert fluid either to a designated waste tank or safely back into the city water system – depending on its composition and safety level.

## Objectives

The objectives of the project were determined through communication with the client:

- Design must detect product in fluid under 1 min of initial exposure to sensor
- Establish typical wastewater parameter values and product concentrations seen in day-to-day plant operation
- Present client with full design, full report, and bill of materials by April 24, 2026

## Constraints

The performance criteria for the implemented design were determined through communication with the client:

- Divert waste fluid to waste tank if there is a presence of related sugars exceeding a TOC level of XXX mg/L
- Divert waste fluid to waste tank if there is a presence of related sugars exceeding a COD level of XXX mg/L
- Design must work with waste pipe diameter of XXX in
- Design must withstand flow rate of ≤ XXX gpm and temperature of ≤ XXX°C
- Design cannot disturb concrete flooring in any manner
- Project must be completed in designated timeline of September 2025 – April 2026
- Solution must not exceed budget of \$250,000

## Design Alternatives

Design alternatives were scored using a decision matrix, shown in Table 1, with the following weighted criteria:

- Efficacy – 30%
- Reliability – 25%
- Ease of Installation/Use – 20%
- Maintenance and Upkeep – 20%
- Cost – 5%

### Thornton TOC Sensor (6.40)

- TOC sensor specifically designed for pharmaceutical waste applications
- Sensor capabilities exceed pressure, temperature, maintenance frequency, and flow rate requirements
- Does not reach required detection limits of TOC

### UviTec Submersible Probe (6.55)

- Rapid detection capabilities of TOC and/or COD
- Reaches required detection limit for TOC in waste line
- Does not meet required temperature capabilities

### Badger Meter carbo::lyser V3 Organic Carbon Spectrometer Probe (8.2)

- Multi-parameter probe with ability to detect COD and TOC levels simultaneously
- Meets all required capabilities for operation
- 30 second detection rate, but with two staggered probes reduces detection time to 15 seconds
- Integrates with nano::station system, improving ease of use and maintenance

Table 1. Design alternatives decision matrix.

Criteria	Efficacy	Reliability	Ease of Use	Maintenance and Upkeep	Cost	Weighted Total Score
Weight (%)	30	25	20	20	5	100
Carbo::lyser V3 II (COD & TOC)	8	7	9	10	5	8.20
Uvitec TOC sensor	7	6	6	7	7	6.55
Thornton TOC Sensor	6	6	9	5	6	6.40

## Selected Design

### COD and TOC Background

- Chemical Oxygen Demand (COD): the amount of oxygen required to chemically oxidize both organic and inorganic pollutants
- Total Organic Compound (TOC): the amount of carbon in organic compounds
- Sugars of interest have 40% carbon composition

### COD and TOC Sensors

- Both utilize Ultraviolet Visible (UV-Vis) Spectroscopy
- COD Sensors: measure the absorption of UV light at 254 nm
- This is where organic compounds absorb light
- TOC Sensors: measure the change in electrical conductivity at 185nm
  - Measures the amount of carbonic acid created, carbonic acid
  - TOC and carbonic acid created have a direct proportional relationship

Our selected final design approach is the Badger Meter carbo::lyser probe integrated with the nano::station system.

### Design Attributes

- COD max measurement: 10,000mg/L
- TOC max measurement: 3,300mg/L
- Detection Rate: 15s (staggered sensors)
- Max temperature: 50°C

### Standards, Regulations, and Safety Considerations

Pharmaceutical Wastewater and Environmental Monitoring:

Installation:

- ISO 15839:2003
- ISO 24522:2019
- ISO 21676:2019
- ISO 6060:1989
- ISO 20236:2024
- ISO 17025:2017
- ISO 14001:2015

Safety concerns for installation, operation, and maintenance are reliant on:

- OSHA 29 CFR 1910.335
- OSHA 29 CFR 1910.146
- OSHA 29 CFR 1910.305
- OSHA 29 CFR 1926 Subpart AA
- OSHA 29 CFR 1926.405

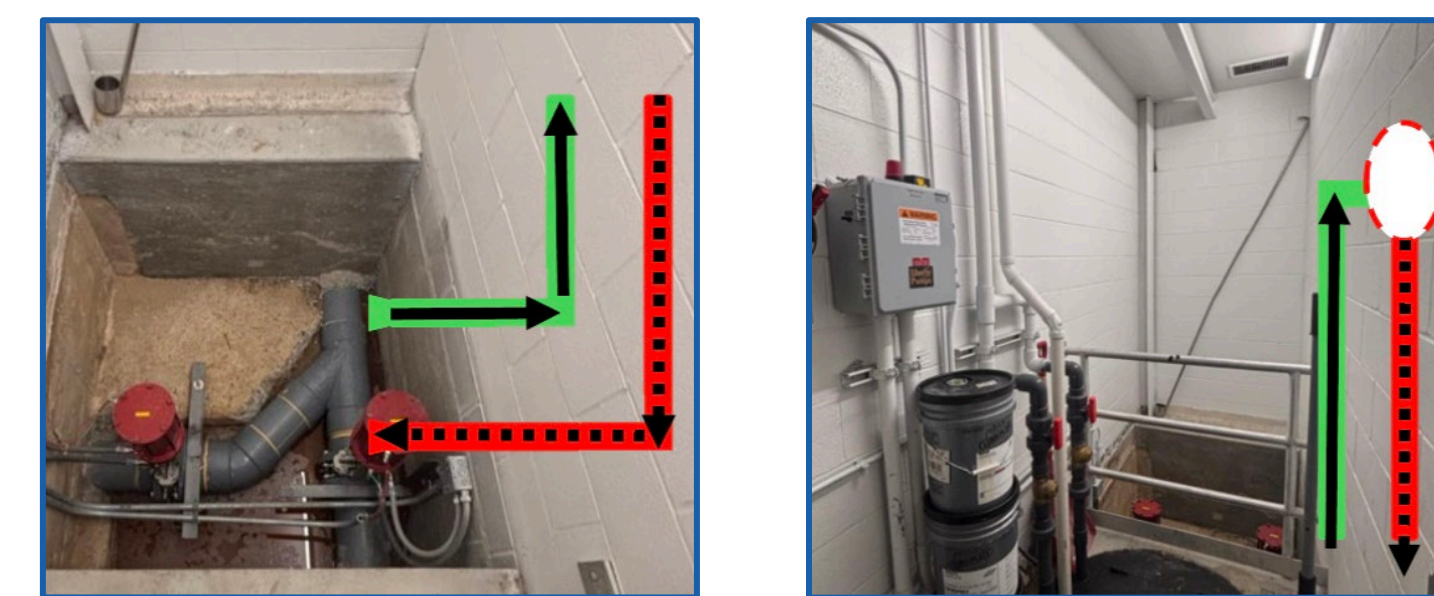


Figure 4. Proposed piping to and from main wastewater pipeline.

Number	Component Name
1	con:cube
2	con:ect
3	s:can compressor
4	Vertical sensor carrier mount
5	Spectrometer flow-cell (bypass set up)
6	Cleaning valve
7	carbo::lyser V3

Figure 5. Badger Meter nano::station (Badger Meter, 2023).

## Design Implementation

- The design will utilize a bypass set-up driven by an industrial peristaltic pump
- Multi-stage reduction will be used to translate the bypass diameter needed for sensor system as shown in Figure 6

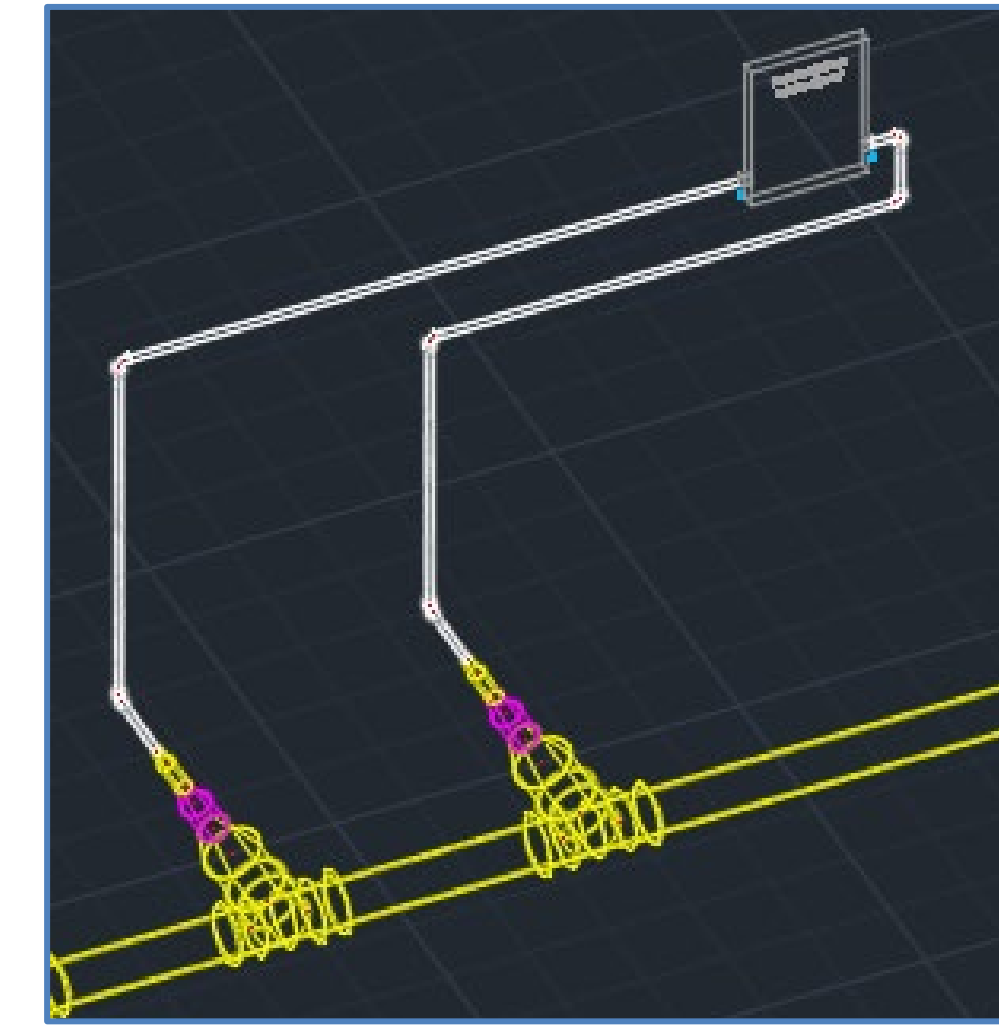


Figure 6. Visual representation of bypass system from waste line (dimensions are not accurate, for visual aid only).

- Each sensor will be installed into a flow cell, oriented with connection ports that face upwards as seen in Figure 7
- Flow cell also has removable window in center for manual cleaning purposes

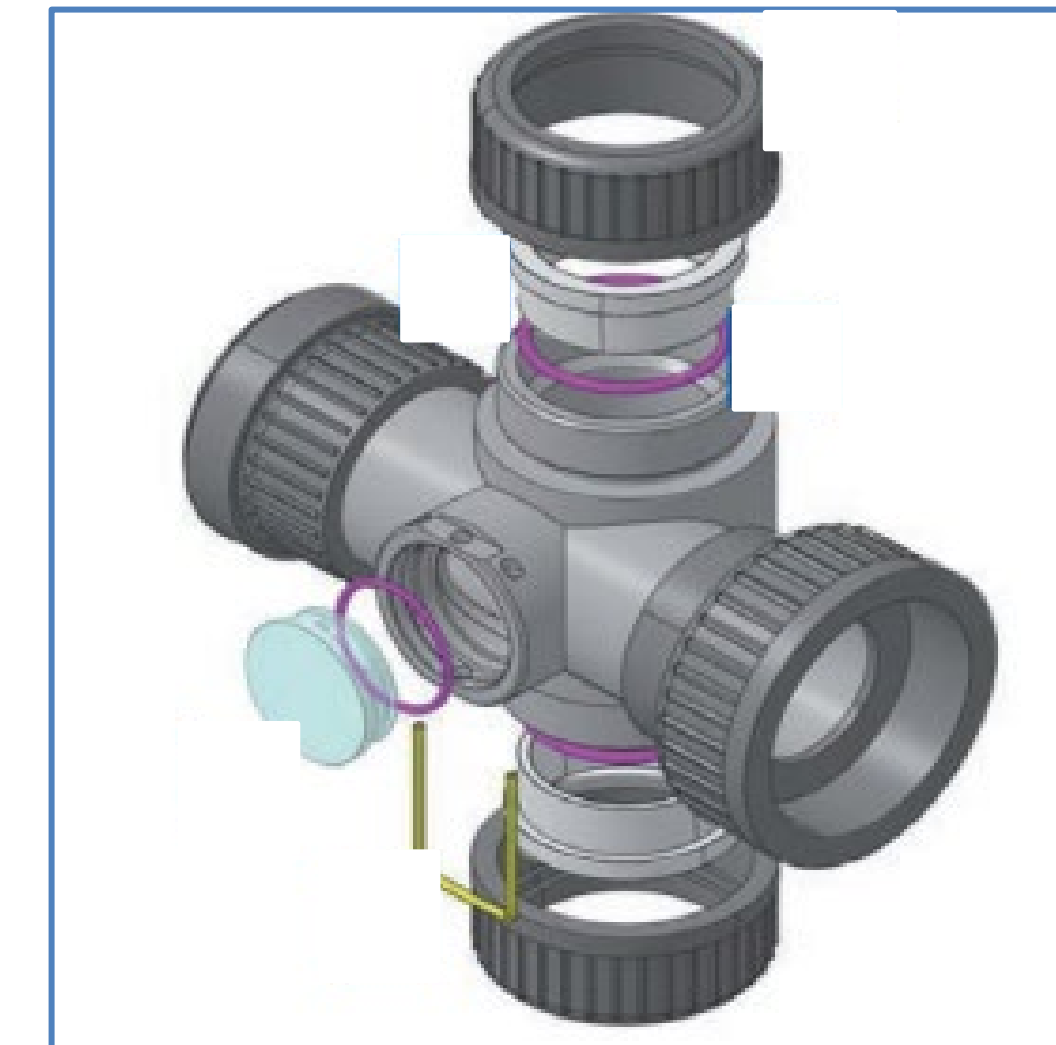


Figure 7. Flow cell setup for wastewater (part no. F-48-V3) (Badger Meter, October 2025).

- The nano::station system will be programmed for "one or the other" state diversion, meaning if either probe detects a COD or TOC level above the threshold, diversion will occur
- Badger Meter's software allows for monitoring and diagnostics of the probes, as well as data output via TCP/IP connection as shown in Figure 8
- Local calibration will be required for accurate measurements, due to Perrigo's wastewater composition
- Samples must be collected so they can be compared to the global standard settings to offset and align to accurate measurements

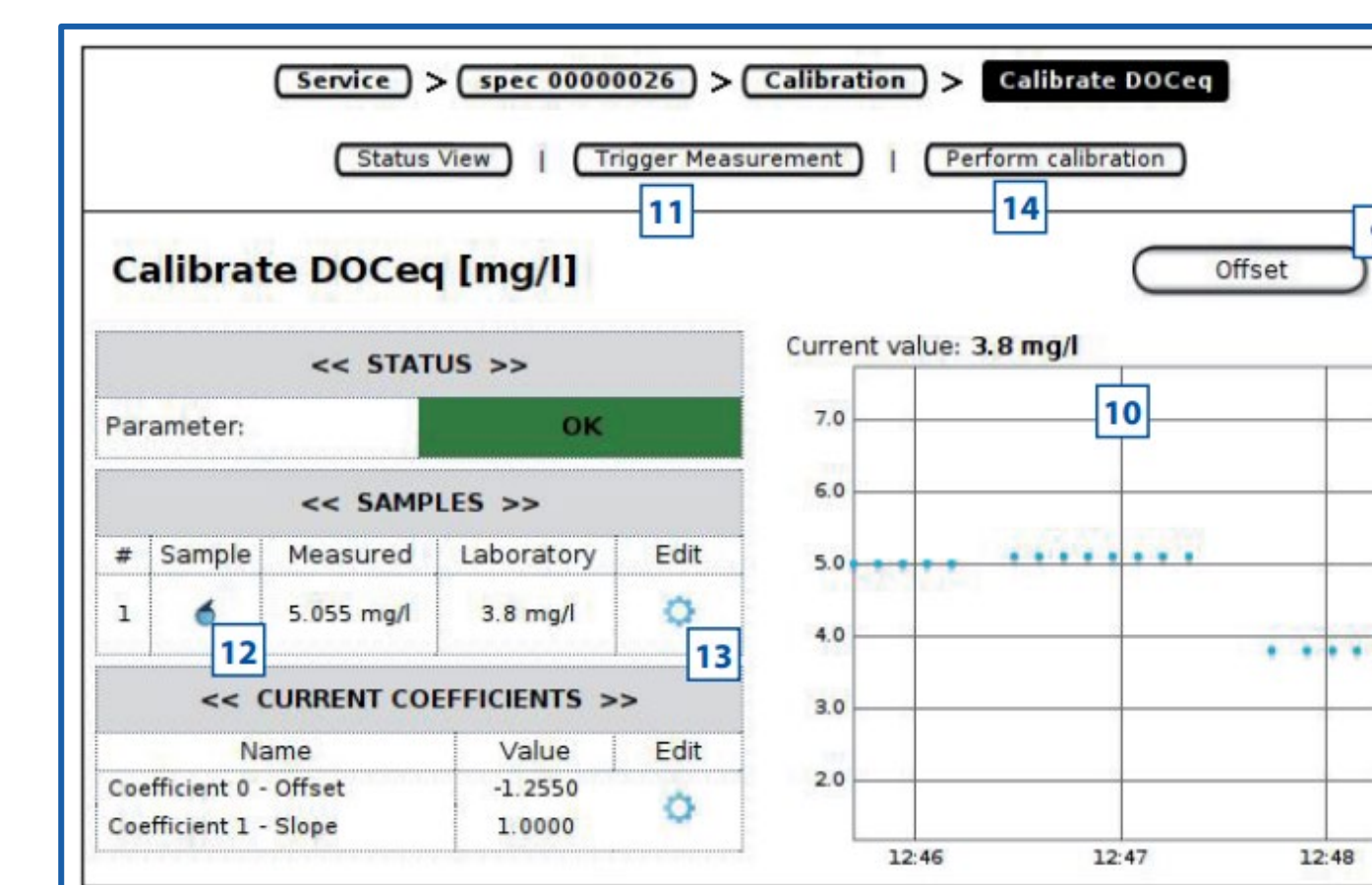


Figure 8. Badger Meter software interface (Badger Meter, October 2025).

## Economics

Life Cycle Cost (LCC):

$$LCC = C_{ic} + C_{in} + C_o + C_e + C_m + C_d - SV \quad (1)$$

Table 2: LCC calculation by components

Variable	Description	Value
$C_{ic}$	Cost of Design & Planning	\$52,852 as per quote and online vendors.
$C_{in}$	Cost of Installation	\$0 as it will be done by existing personnel at Perrigo.
$C_o$	Cost of Operation	\$0 as this system will be automated.
$C_e$	Cost of Energy Consumption	Estimated as \$2,930.58 for 10 years at an interest rate of 4.28%.
$C_m$	Cost of Maintenance	Estimated as 10% of sensor's cost at \$1,860 which totals to \$3,720.
$C_d$	Cost of Removal and Disposal	Estimated as 5% of sensor's cost at \$930 per sensor which totals to \$1,860.
SV	Salvage Value	Estimated as 5% of sensor cost, which provides the value of \$930 per sensor which totals to \$1,860.
LCC	Life Cycle Cost	Estimated as \$59,502.58 for 10 years.

LCC: \$59,503

Payback Period: 1.89 years

Return on Investment (ROI): 257%

Risk Management:

$$Risk = Probability * Consequence * \# \text{ of Spills} \quad (2)$$

$$Risk_{current} = \$280,000$$

$$Risk_{system} = \$67,920$$

$$Risk \text{ Mitigation} = Risk_{current} - Risk_{system} \quad (3)$$

$$Risk \text{ Mitigation} = 212,080$$

Does not include intangible concerns:

- Bad PR
- Harm to surrounding environmental (i.e. aquatic life and adverse human health effects from interaction)
- Hypothetical loss of sales due to bad-brand practice
- Revocation of access to Allegan's City Water Dept. wastewater treatment facility

## Key Takeaways

- Our team worked with Perrigo to create a solution to detect and divert waste fluid to the correct location.
- After review, the final design was a nano station and sensor system based on COD and TOC levels with system monitoring and light warnings.
- In the future, Perrigo could integrate this set-up in other plants.
- Perrigo could conduct testing of the wastewater for future studies and sensitivity analyses.

## Acknowledgements

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