NAWI National Alliance for Water Innovation

NAWI 5.17: Data-Driven Fault Detection and Process Control For Potable Reuse with Reverse Osmosis

Task 5.17.1.3: Non-Parametric Statistics for RO LRV Modeling

- Intact reverse osmosis (RO) removes pathogens by over 99.999%.
- Online surrogates can show a minimum log reduction value (LRV) that is being achieved at any time. However, the sensors for these surrogates are prone to erroneous outliers, making the data distribution skewed.
- We proposed an advanced statistical method called the Shewhart Sign Chart.
- This method reduced alarms by ignoring non-consecutive outliers.
- With a rolling window of 12 hourly points, it would trigger for true events in 3 hours (Figure 1).

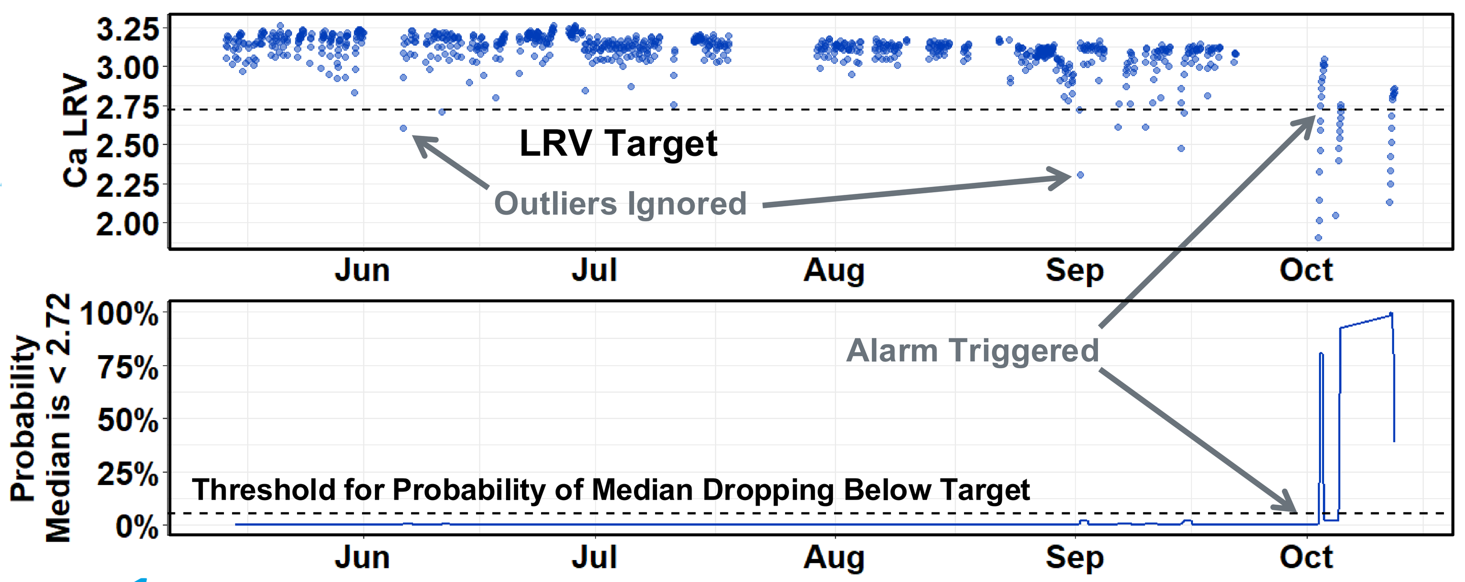
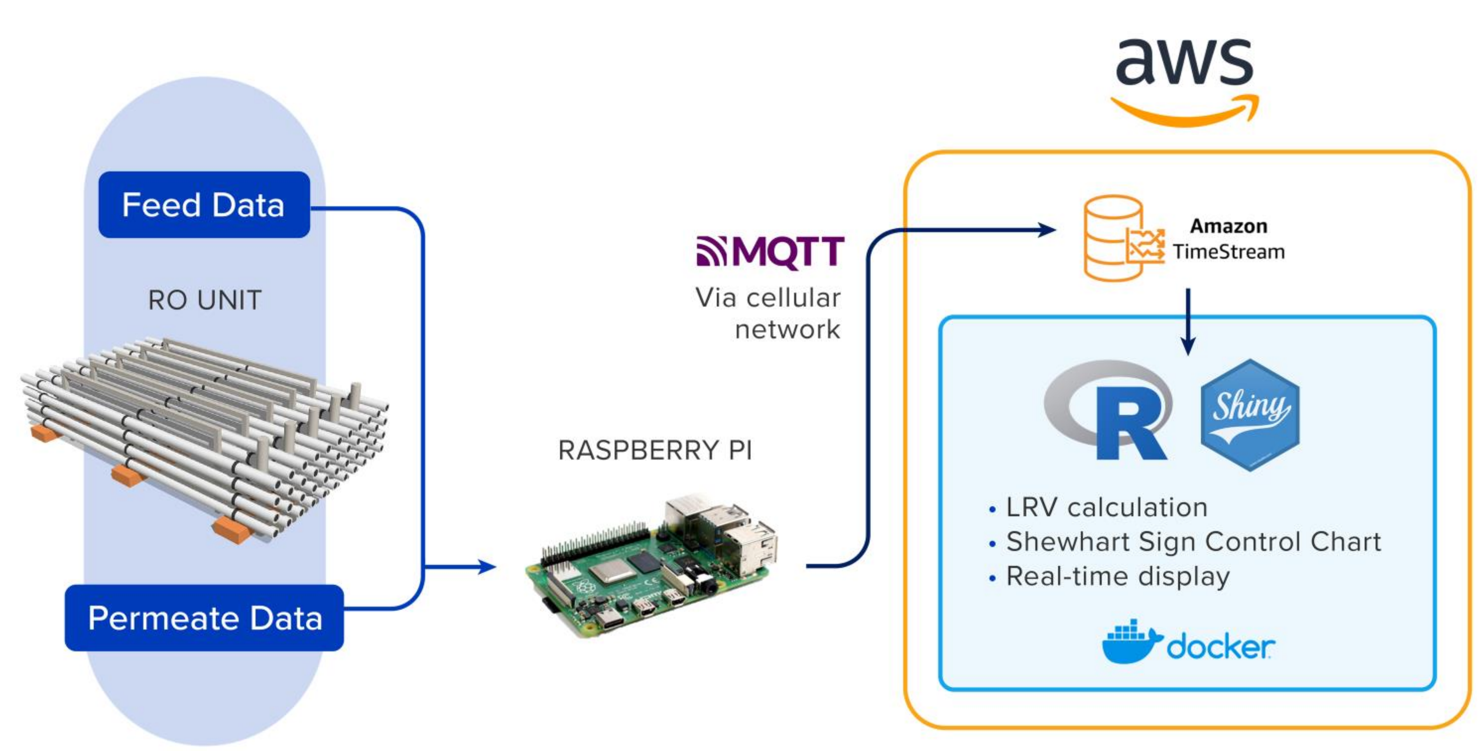


Figure 1

- This method has new been implemented on full-scale RO via a cloud dashboard at OCWD (Figure 2).



Task 5.17.1.4: Supervised Machine Learning Regression for N-Nitrosodimethylamine (NDMA)

- NDMA is a key disinfection byproduct in reuse but monitoring NDMA in real-time is not possible with commercial sensors.
- In RO-based reuse, UV/AOP is operated conservatively, assuming the maximum historical NDMA concentration.
- Machine learning (ML) was explored to develop an NDMA soft sensor based on existing data from OCWD.
- NDMA soft sensors could make potable reuse more resilient and efficient by dynamically updating UV/AOP control to reflect actual influent NDMA concentrations.
- To achieve a final NDMA concentration of 0.69 ng/L, the site could reduce their UV dose by 21-29% (depending on the desired factor of safety, Figure 3), using a hybrid statistical-ML approach to predict influent NDMA.

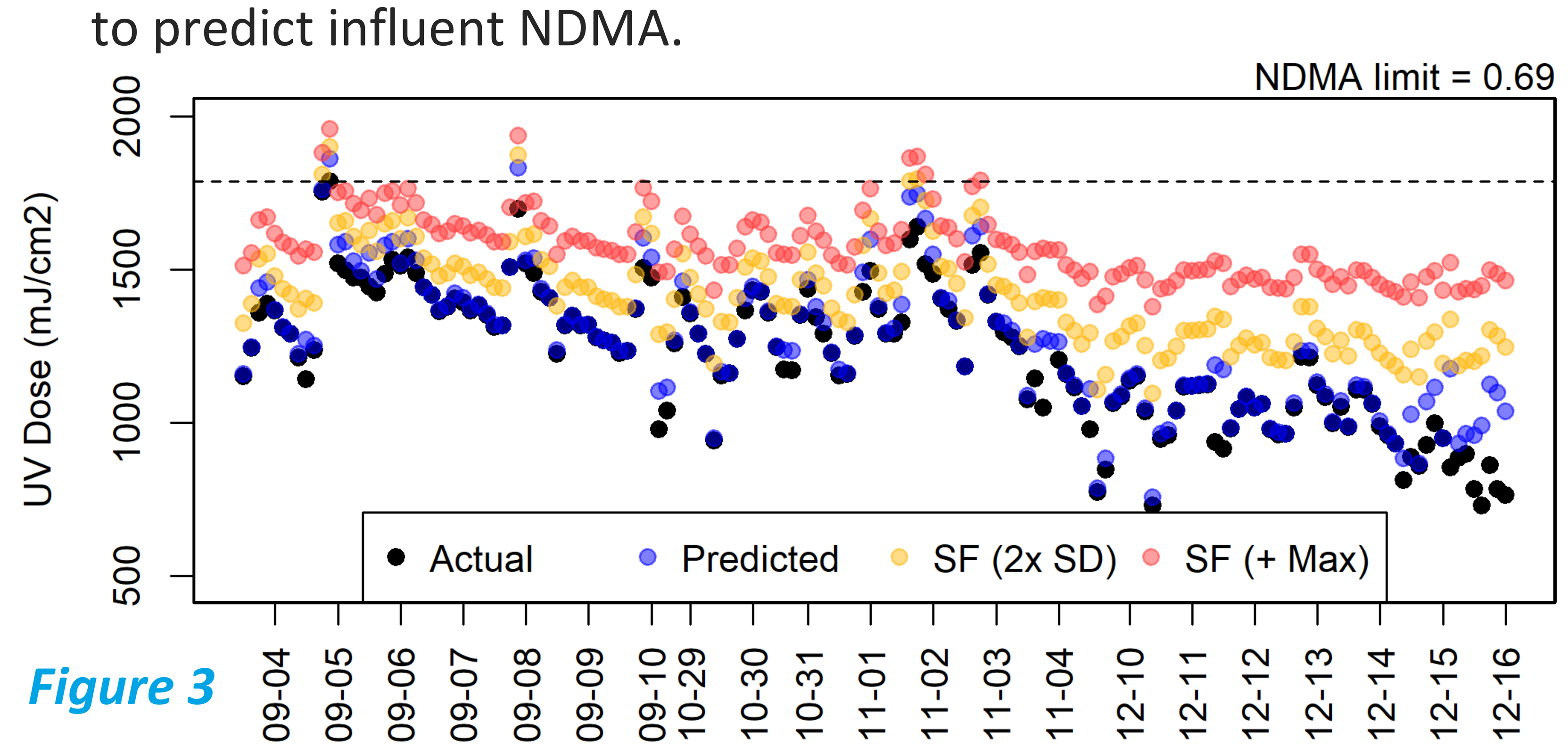
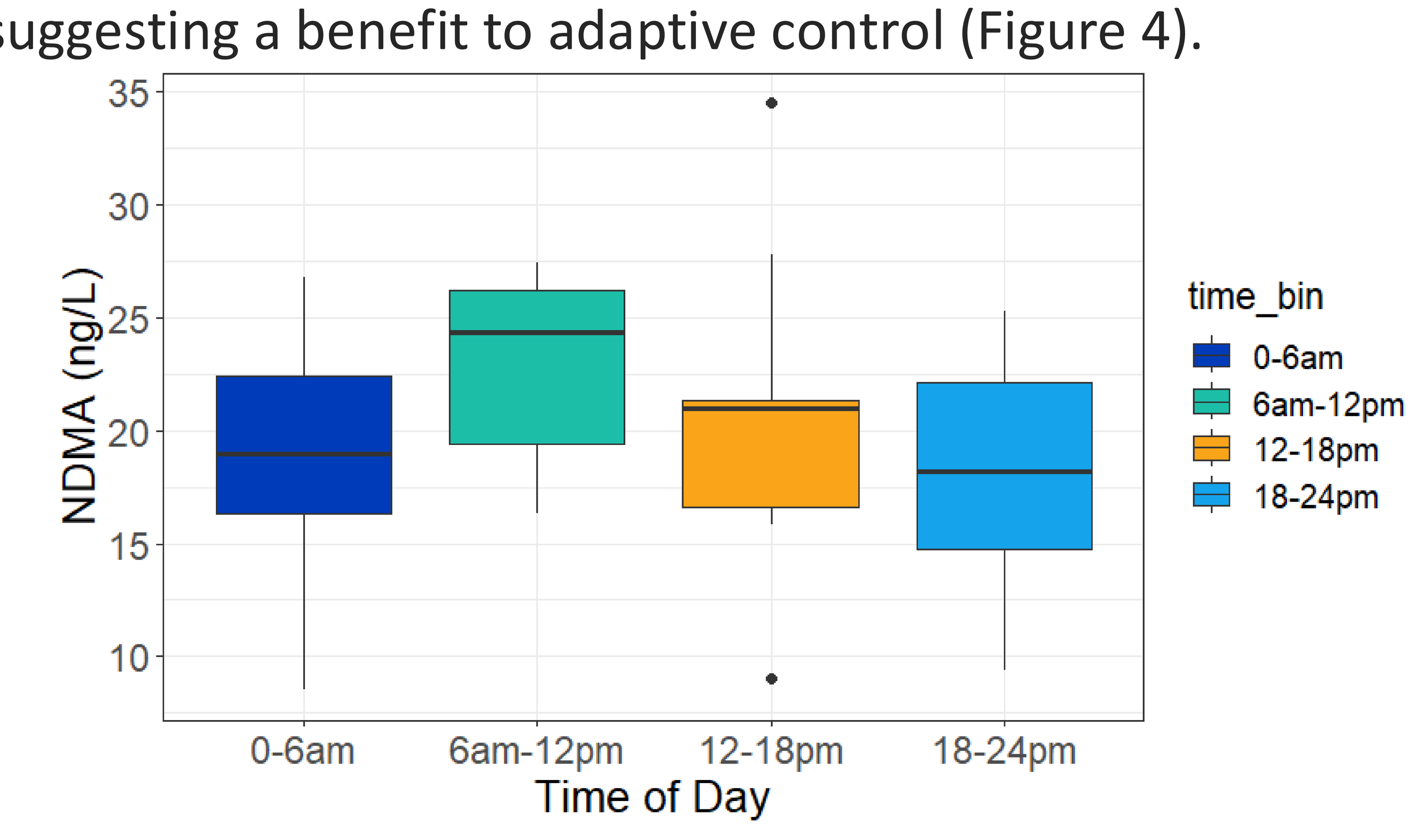


Figure 3

- Preliminary data from a new site indicated a daily pattern, suggesting a benefit to adaptive control (Figure 4).



NAWI CONNECTIONS

Period of Performance: 2022-2025

Challenge Area/Topic Area: Municipal Wastewater; Autonomous Water; Resilient Treatment

NAWI Leverage: This project is collaborating with NAWI Project 5.08 Advanced Process Controls – Autonomous Control and Optimization via a Project Enhancement Grant (PEG).

KEY FINDINGS AND CONCLUSIONS

Task 1.3

Key Findings:

- Most RO LRV surrogates evaluated (Ca, S, Sr, TOC, and Peak C Fluorescence) were not normally distributed; most were left-skewed and S was bimodal.
- Left-skewed data would cause excessive alarms if assumed normal.
- A Shewhart Sign Chart could detect true events in 3 hr while reducing alarms by >50% compared to alarms on single points.

Conclusions:

- Shewhart Sign Chart for RO LRV monitoring would meet the **Reliability & Availability** pipe parity metric by reducing false alarms by 50%.
- Scale-up is feasible through real-time cloud dashboards.

Task 1.4

Key Findings:

- NDMA concentrations are highly correlated to pressure drops across RO membranes and influent ammonia concentrations.
- The optimal model inputs depend on model type. PCA is an effective method of dimension reduction for process units like RO-banks with a large number of correlated features. In this case, all PCA-based models performed as well or better than mRMR, a feature selection approach.
- While different model types may compare similarly on average, many predict extreme outliers in simulated real-time forecasts (e.g., support vector machines and k-nearest neighbors).

Conclusions:

- Support vector machines with PCA dimension reduction for the RO units can successfully predict NDMA. Follow-on work includes an expanded sampling campaign for deployment.

ACKNOWLEDGEMENTS

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