Reducing Energy Consumption in Wastewater Treatment through Optimized Aeration and Sludge Recirculation Rate

Thanyaret Puengwong[1], Kodchanika Jeena[1], Pattanapong Thangsunan[1], Nuttee Suree[1]
Tanayot Panphew[2], Anusorn Rernthaisong[2], Nutakan Phichai[2]
[1]Division of Biochemistry and Biochemical Innovation, Department of Chemistry, Faculty of Science, Chiang Mai University
[2]Beer Thai (1991) Public Company Limited
Email address: thanyaret_pu@cmu.ac.th

Abstract

The “Activated Sludge” process is a wastewater treatment method which requires high levels of energy consumption, particularly in the operation of aerators and the return sludge pumps. These requirements directly impact industrial operational costs. This research aims to reduce electricity consumption within the activated sludge system of Beer Thai (1991) Public Company Limited. The study focused on the efficiency improvement of aerators and Return Activated Sludge (RAS) rates and compared with the 2025 operational performance as a baseline. The methodology involved the adjustment of the RAS ratio from the baseline of 150% down to the levels between 145% and 130% with the reduction of Dissolved Oxygen (DO) levels to a controlled range of 2.0–2.4 mg/L. The results indicated that both reduction of the RAS ratio and optimization of DO levels significantly caused a decrease in Specific Energy Consumption (SEC). Reducing the RAS ratio to 130% yielded the highest efficiency, with an average SEC of 0.0469 kWh/m^3, representing a 13.37% reduction from the baseline and an estimated annual cost saving of 36,907 Baht. Simultaneously, the optimized DO control resulted in an average SEC of 0.697 kWh/m^3, a 10.73% reduction from the baseline, contributing to an estimated annual saving of 426,182 Baht. Throughout the study, the quality of biological characteristics of the activated sludge in an aeration tank was improved. These results demonstrate that optimizing machinery performance at appropriate ratios can effectively reduce costs and achieve sustainable long-term energy savings.

Introduction

In beverage industry, the Activated Sludge Process is a wastewater treatment method characterized by high electrical energy consumption, particularly in the aeration stage for dissolved oxygen (DO) control and sludge recirculation to maintain microbial efficiency. However, operational data analysis reveals that energy usage in these processes is currently excessive, impacting both operational costs and stability of the microbial system. Therefore, this study focuses on optimization of machinery operations to achieve maximum energy reduction while maintaining effluent quality in accordance with regulatory standards. This modified approach is expected to enhance the overall efficiency and long-term stability of the wastewater treatment system.

Objectives

- To study the wastewater treatment system and identify key parameters affecting the factory's treatment efficiency.
- To analyze and optimize the Return Activated Sludge (RAS) rate to improve the overall efficiency of the wastewater treatment system.
- To evaluate and reduce the energy consumption of the aeration system while maintaining microbial quality.

Methodology

1. Baseline Data Analysis



Baseline data from Quarter 2025

- Electricity consumption: Return Activated Sludge Pumps and Aerators
- Dissolved Oxygen (DO) levels
- Return Activated Sludge (RAS) rates

2. Return Activated Sludge Rate & Dissolved Oxygen Optimization



Adjusted RAS rates and DO setpoints via the computerized control system (SCADA)

Return Activated Sludge Rate

- Initial Baseline: 150% RAS
- Gradually reduced the rate in **5% increments** (150% —> 145% —> 140% —> 135% —> 130%)

Dissolved Oxygen (DO) control

- Existing Range: 2.2 - 2.7 mg/L
- Optimized Range: 2.0 - 2.4 mg/L

3. Microbiological Assessment



Wastewater Sample from Aeration tank



Placed 3–4 drops of well-mixed sludge onto a clean glass slide.

Placed a cover slip over the sample



Microscopic Identification and Population Counting

4. Energy Analysis

Calculated Specific Energy Consumption (SEC) and total annual electricity cost savings

$$SEC = \frac{\text{Electricity Consumption (kWh)}}{\text{Total Wastewater Treatment Volume (m}^3\text{)}}$$

Results & Discussion

Return Activated Sludge Optimization

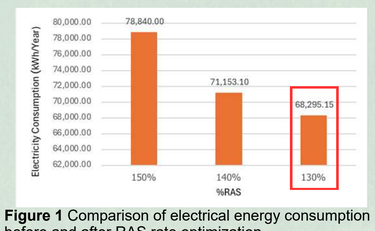


Figure 1 Comparison of electrical energy consumption before and after RAS rate optimization

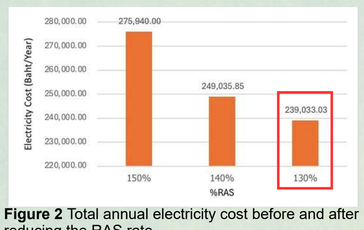


Figure 2 Total annual electricity cost before and after reducing the RAS rate.

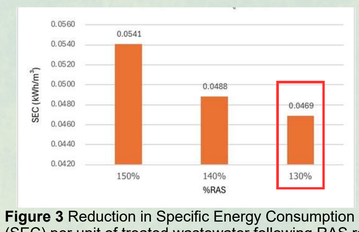


Figure 3 Reduction in Specific Energy Consumption (SEC) per unit of treated wastewater following RAS rate optimization

Dissolved Oxygen Optimization

- Existing Dissolved Oxygen Range: 2.2-2.7 mg/L (Based on Quarter 2025 data)
- Optimized Dissolved Oxygen Range: 2.0-2.4 mg/L (Experimental Setpoint)



Figure 4 Comparison of electrical energy consumption before and after DO setpoint optimization



Figure 5 Electricity cost before and after DO setpoint optimization

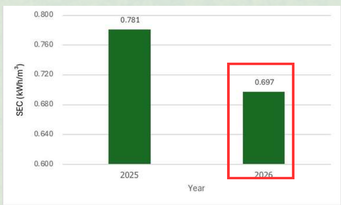


Figure 6 Reduction in Specific Energy Consumption (SEC) following Dissolved Oxygen optimization

Microbiological Assessment

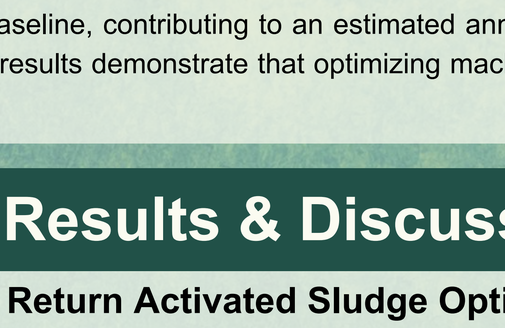


Figure 7 Relative Predominance of Microorganisms

A predominance of **Stalked Ciliates** within a diverse microbial community indicated a well-stabilized sludge process and an optimal Sludge Age, leading to high-quality effluent.

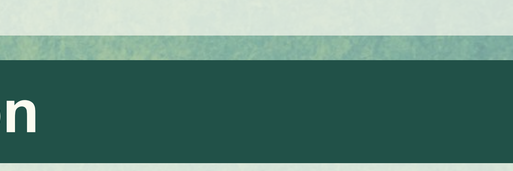


Figure 8 Stalked Ciliates

Return Sludge Ratio: 150%

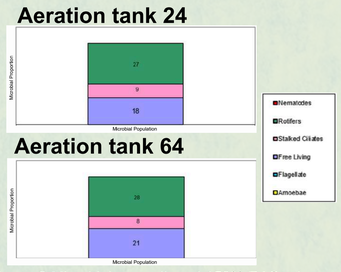


Figure 9 Microbial proportion at 150% RAS rate

Return Sludge Ratio: 140%

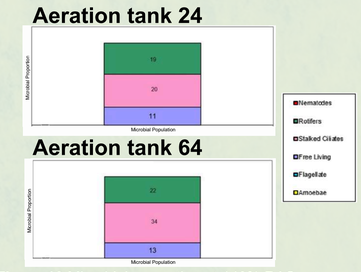


Figure 10 Microbial proportion at 140% RAS rate

Return Sludge Ratio: 130%

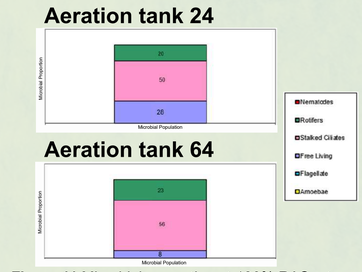


Figure 11 Microbial proportion at 130% RAS rate

Before
Dissolved Oxygen (2.2-2.7 mg/L)

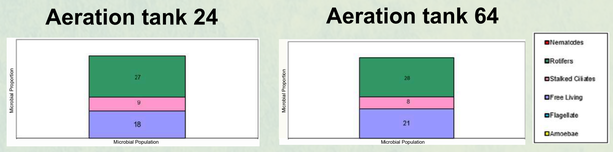


Figure 12 Microbial proportion at 2.2-2.7 mg/L DO

After
Dissolved Oxygen (2.0-2.4 mg/L)

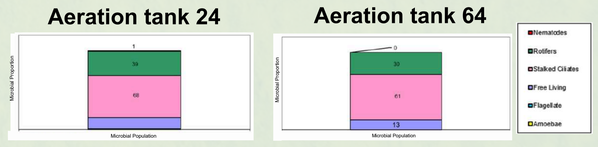


Figure 13 Microbial proportion at 2.0-2.4 mg/L DO

Conclusion

- Operating at a 130% RAS rate yielded the highest efficiency, achieving an annual electricity saving of 36,907 Baht/year.
- Maintaining Dissolved Oxygen levels between 2.0–2.4 mg/L resulted in a significant annual electricity saving of 426,181.60 Baht/year.
- A significant increase in Stalked Ciliates indicated that the Activated Sludge system returned to "Good Settling" conditions.

Acknowlagements

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- Division of Biochemistry and Biochemical Innovation, Department of Chemistry, Faculty of Science, Chiang Mai University
- Beer Thai (1991) Public Company Limited

References

- มั่นสิน ตัณฑุลเวศม์. (2550). การบำบัดน้ำเสียทางชีวภาพ. กรุงเทพฯ: สำนักพิมพ์แห่งจุฬาลงกรณ์มหาวิทยาลัย.
- Spellman, F. R. (2020). Handbook of Water and Wastewater Treatment Plant Operations (4th ed.). CRC Press.
- Du, X., Wang, J., Jegatheesan, V., & Shi, G. (2018). Dissolved oxygen control in activated sludge process using a neural network-based adaptive PID algorithm. *Applied Sciences*, 8(2), 261. https://doi.org/10.3390/app8020261