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

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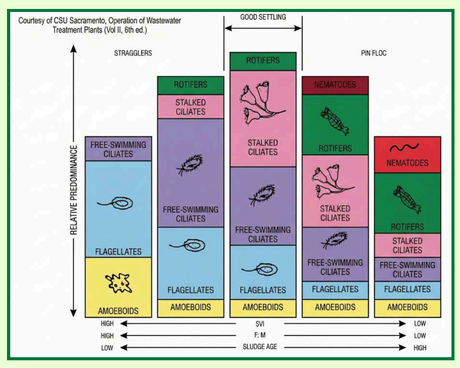
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ABSTRACT

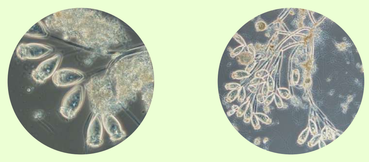
The "Activated Sludge" process is a wastewater treatment method which requires high levels of energy consumption, particularly in the operation of aerators and the return sludge pumps. These requirements directly impact industrial operational costs. This research aims to reduce electricity consumption within the activated sludge system of Thai Beverage (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 0.0364 kWh/m3, representing a 32.71% reduction from the baseline and an estimated annual cost saving of 33,714 Baht. Simultaneously, the optimized DO control resulted in an average SEC of 0.543 kWh/m3, a 30.43% 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 the beverage industry, the Activated Sludge (AS) process is essential for organic degradation but remains highly energy-intensive. Maintaining Dissolved Oxygen (DO) through aeration and Microbial Concentration through Return Activated Sludge (RAS) represents a significant portion of operational costs. Analysis of current operations reveals continuously rising energy consumption and excessive sludge recirculation rates, which inflate costs and risk microbial instability. Therefore, optimizing machine operation to align with actual wastewater loads through biochemical and engineering principles is crucial. By finding this balance, the project aims to minimize electricity consumption while ensuring treatment efficiency strictly adheres to legal effluent standards.



Relative Predominance of Microorganisms as a Process Control Indicator: The 'Good Settling' phase signifies the optimal equilibrium for maximum treatment efficiency and superior effluent clarity



Stalked Ciliates: The Hallmark of Crystal Clear Effluent

OBJECTIVES

- To study the wastewater treatment system and identify key parameters affecting treatment efficiency.
- To evaluate and reduce energy consumption in the aeration process while maintaining effluent quality within standard limits.
- To analyze and optimize the Return Activated Sludge (RAS) rate to ensure peak system performance.

METHODOLOGY

1 Baseline Data Analysis

Baseline data from Quarter 2025 Electricity consumption:

1. Return Activated Sludge Pumps and Aerators
2. Dissolved Oxygen (DO) levels
3. Return Activated Sludge (RAS) rates

2 Optimization

1. Stepwise reduction of RAS rate by 5%, 10%, 15%, and 20% from the baseline of 150%. (150 → 145 →140→ 145→ 130)
2. Adjusted DO Setpoint to 2.0 – 2.4 mg/L, reduced from the initial range of 2.2 – 2.7 mg/L.

3

Wastewater Sampling → Slide Preparation → Microscopic Analysis

4 Energy Analysis

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

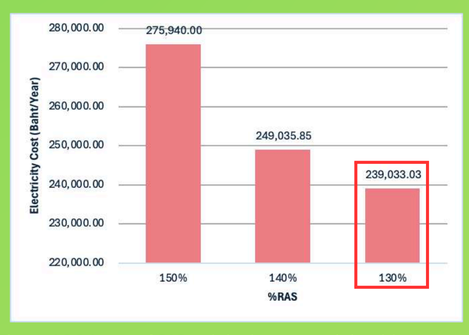
$$SEC = \frac{\text{Electricity Consumption (kWh)}}{\text{Total Wastewater Treatment Volume (m}^3\text{)}}$$

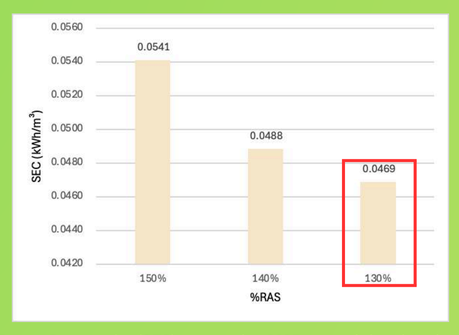
The analysis aims to identify potential cost reduction opportunities and optimize the overall electricity expenditure.

RESULTS & DISCUSSION

Return Activated Sludge Optimization

The impact of RAS optimization indicates a consistent downward trend in both annual electricity costs and Specific Energy Consumption (SEC). Reducing the RAS rate to 130% significantly improved energy efficiency compared to the 2025 quarterly benchmarks.





Figures 1 & 2: Impact of RAS optimization on annual electricity costs and Specific Energy Consumption (SEC) compared to 2025 quarterly benchmarks.

Dissolved Oxygen Optimization

The optimization of Dissolved Oxygen (DO) levels effectively enhanced energy performance by mitigating over-aeration within the system. This strategic adjustment led to a significant reduction in both annual electricity expenditures and Specific Energy Consumption (SEC) in 2026 compared to the previous year

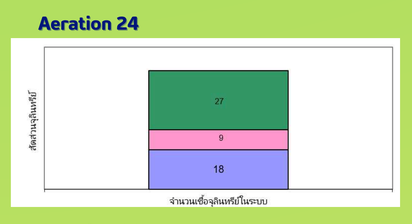




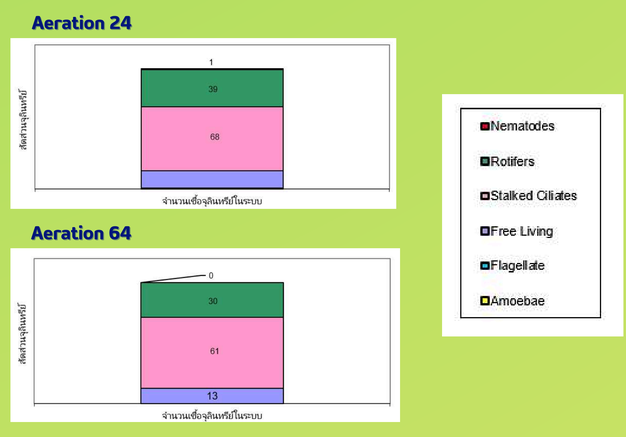
Figures 3 & 4: Comparison of annual electricity costs and Specific Energy Consumption (SEC) before and after Dissolved Oxygen (DO) optimization

The adjustment of %RAS and DO levels triggered a shift from a Rotifer-dominant 'Old Sludge' state to a Stalked Ciliate-dominant 'Good Settling' condition. This transition effectively enhanced floc stability and effluent clarity, indicating a more stable and optimized biological system.

Before



After



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 indicates that the Activated Sludge system has returned to "Good Settling" conditions.

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