ASSESSMENT OF THE RELATIONSHIP BETWEEN MICROBIAL COMMUNITY STRUCTURE AND WATER QUALITY FROM THE ACTIVATED SLUDGE SYSTEM OF WASTEWATER TREATMENT PLANT

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Abstract

This study aimed to evaluate water quality and investigate microbial diversity in the activated sludge system of the Water Quality Control Plant. Samples were collected from July 2024 to January 2025. Water quality parameters included temperature (14.9–26.0°C), pH (6.49–8.00), dissolved oxygen (6.81–7.34 mg/L), conductivity (400–730 µS/cm), biochemical oxygen demand (4.81–5.12 mg/L), total dissolved solids (198 mg/L), alkalinity (178–357 mg/L), hardness (300 mg/L), sludge volume index (60–250 mg/L), fat oil and grase (4-15 mg/L), phosphate (2-4 mg/L), nitrate (0.5 mg/L) nitrite and ammonia (0 mg/L), and coliform/fecal coliform (>1,600 MPN/100mL). Dominant microorganisms observed under a microscope included *Aphanocapsa* sp., *Microcystis* sp., and *Coleps elongatus*, which showed the highest densities. Among them, *Aphanocapsa* and *Microcystis* are cyanobacteria known to cause eutrophication (algal blooms) under high phosphate and nitrogen conditions. Testate amoebae were abundant in early samples, indicating high organic content that later declined, possibly due to environmental shifts or microbial competition. Other phytoplankton, such as *Scenedesmus* sp., *Navicula* sp., and *Chlorella* sp., appeared in low abundance, suggesting suboptimal light or pH conditions related to inconsistent system control. Zooplankton, including Rotifera and *Daphnia* sp., were occasionally present, reflecting possible variations in dissolved oxygen or organic toxicity. Transient species such as purple sulfur bacteria indicated short-term anaerobic events. Overall, the study highlights the dynamic interactions between microbial communities and water quality parameters in the activated sludge process, emphasizing their potential as bioindicators for treatment efficiency.

Keywords: Microbial community structure, Activated sludge, Water quality

Introduction

Domestic wastewater is a significant source of environmental pollution in urban areas, primarily originating from household activities such as bathing, washing, and cooking, which account for approximately 80% of all wastewater generated globally (UNEP, 2016; WHO, 2006). The composition of domestic wastewater typically includes organic and inorganic compounds, nutrients (nitrogen and phosphorus), suspended solids, fats, oils, and grease, and a diverse range of microorganisms, all of which have significant implications for water quality, aquatic ecosystems, and public health (Tchobanoglous et al., 2003; Metcalf & Eddy, 2014). Untreated domestic wastewater in urban areas degrades water quality, causing pollution in rivers, lakes, and groundwater. The high levels of nutrients, especially nitrogen and phosphorus, promote eutrophication, harmful algal blooms, and biodiversity loss, while harmful microorganisms pose significant public health risks. According to Thongkao (2015, 2019, 2020), the presence of these pollutants in domestic wastewater further exacerbates water quality issues, emphasizing the importance of addressing nutrient overload and microbial contamination. Therefore, effective wastewater treatment is essential to protect both the environment and human health. Sustainable management and innovative treatment technologies are essential for reducing pollution, protecting water resources, and mitigating the adverse effects of wastewater pollution.

Among the biological treatment technologies, the Cyclic Activated Sludge System (CASS) has been widely adopted for the treatment of mixed domestic wastewater due to its operational efficiency, space-saving design, and flexibility. The system integrates aeration, sedimentation, and effluent discharge within a single tank, enabling efficient nutrient removal under alternating aerobic and anoxic conditions (Fan et al., 2019). The Chatuchak Wastewater Treatment Plant, located in Bangkok, Thailand, is a large-scale facility utilizing the CASS process. It serves a catchment area of approximately 33.4 km^2, treating up to 150,000 m^3/day of wastewater, and represents an important model for evaluating microbial and physicochemical dynamics in tropical wastewater systems.

Microorganisms play a central role in the activated sludge process. Bacteria are responsible for the degradation of organic matter, nitrification, and phosphate removal; protozoa and metazoa contribute to the control of bacterial populations and the clarification of effluent, while phytoplankton and cyanobacteria participate in nutrient uptake and oxygen generation through photosynthesis (Bitton, 2011; Madoni, 2011). Species such as *Scenedesmus* sp. and *Chlorella* sp. have been reported to reduce nitrogen and phosphorus levels through assimilation and oxygenation processes (Yang et al., 2012; Zhou et al., 2003; Simsek et al., 2008; Silambarasan et al., 2013). Furthermore, testate amoebae, including *Arcella* sp., *Centropyxis* sp., and *Difflugia* sp., have been identified as reliable bioindicators reflecting system stability and organic load (Tomasini-Ortiz et al., 2018).

However, limited studies have examined the relationship between microbial community structure and water quality in tropically activated sludge systems, particularly in the context of Southeast Asia. Understanding these interactions is essential for improving the operational stability of wastewater treatment plants, predicting system disturbances, and developing sustainable management strategies.

Therefore, this study aims to assess the physicochemical characteristics and evaluate the microbial community composition in the activated sludge system of the Chatuchak Wastewater Treatment Plant, Thailand. By identifying dominant microbials and their correlation with key environmental parameters, this research provides insight into microbial dynamics under tropical conditions. It contributes to the optimization of biological wastewater treatment processes.

Research Objectives

1. To evaluate the physicochemical characteristics of wastewater in the activated sludge system of the Chatuchak Wastewater Treatment Plant during different sampling periods.
2. To analyze and identify the dominant microbial communities in the activated sludge system and determine their relationships with key water quality parameters.

Scope of the Research

1. Population Scope

The study focused on wastewater and activated sludge samples from the Chatuchak Wastewater Treatment Plant, Bangkok, Thailand, observing microbial groups such as bacteria, protozoa, phytoplankton, and testate amoebae.

2. Variable Scope

Physicochemical parameters analyzed: temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), phosphate, nitrate, and ammonia. Biological variables included the diversity, abundance, and composition of microorganisms like *Aphanocapsa* sp., *Microcystis* sp., *Coleps elongatus*, *Phacus* sp., and Testate amoebae, along with the relationship between microbial community structure and water quality.

3. Time Scope

Sampling and analyses were conducted from July 2024 to January 2025, covering both dry and wet seasons to capture seasonal variations in microbial dynamics and water quality.

Research Methodology

1. Research Methodology

This study utilized a descriptive–analytical approach to examine the relationship between microbial community structure and water quality in the activated sludge system of the Chatuchak Wastewater Treatment Plant. It combined field sampling and laboratory analyses to assess the diversity and abundance of dominant microbial taxa and their correlation with key environmental parameters, following standard environmental monitoring protocols.

2. Research Steps

Site Selection: Sampling sites were identified within the activated sludge units of the plant.

Sample Collection: Monthly wastewater and activated sludge samples were collected from July 2024 to January 2025.

Water Quality Measurement: Physicochemical parameters (temperature, pH, DO, BOD, TDS, conductivity, phosphate, nitrate, ammonia) were measured.

Microscopic Observation: Microbial taxa were identified and quantified using compound microscopy at 400× magnification.

Data Recording and Statistical Analysis: Data were compiled, and relationships between variables were analyzed statistically.

3. Data Collection

Data was collected via field measurements and laboratory analyses. Water quality parameters were measured using standard methods (EPA, 2017). On-site measurements included temperature, pH, and DO, while BOD, nutrients, and suspended solids were analyzed in the lab. Activated sludge samples were examined microscopically to identify dominant microorganisms, and their relative abundance was recorded.

4. Data Analysis

Statistical analysis was performed to interpret variations in water quality and microbial dynamics. Descriptive statistics were calculated, and Pearson's correlation analysis was used to assess relationships between physicochemical factors and microbial abundance. Principal Component Analysis (PCA) was employed to visualize clustering based on environmental and biological variables. All statistical analyses and data visualizations were conducted using R software.

Research Results

Water Quality

Physicochemical Analysis: Based on the water quality monitoring results from the Water Quality Control Plant over a 6-month period, the pH values ranged from 6.49 to 8.00, with an average of 7.37. These values fall within the appropriate range for Class 3 surface water (5.5 – 9.0), indicating a neutral to slightly alkaline condition that is suitable for aquatic life. BOD ranged from 4.81 to 5.12 mg/L, with some instances exceeding the standard limit of 4 mg/L. This may indicate contamination from organic substances in the water source or insufficient treatment of community waste. However, the Dissolved Oxygen (DO) values were measured between 6.81 and 7.34 mg/L, significantly above the minimum required standard of ≥2 mg/L, indicating that the system can maintain a suitable environment for aquatic life. Nitrate (NO_3^-) concentrations remained consistently low at 0.5 mg/L, while Phosphate (PO_4^{3-}) levels ranged from 2 to 4 mg/L,which reflects the partial reduction of nutrients during the treatment process. This suggests that while there is some success in reducing phosphate levels, there may still be room for improvement in nutrient removal, as high concentrations of phosphate can contribute to eutrophication and other environmental concerns in aquatic ecosystems.

Microbiological Analysis: Throughout the sampling period, both Coliform and Fecal Coliform bacteria levels consistently exceeded 1,600 MPN/100 mL, indicating significant contamination. Although the levels stayed within the Class 3 surface water standards (4,000 MPN/100 mL for Coliform and 2,000 MPN/100 mL for Fecal Coliform), the consistently high values suggest the need for ongoing monitoring and pollution control, especially in areas where water is used for consumption or near populated zones.

Abundance of Microbial Diversity

High Abundance Group (≥60,000 cells/liter): *Aphanocapsa* sp. (Cyanobacteria) was found at an average of 80,750 cells/liter, consistently present in all samples, indicating a high nutrient condition. *Coleps* elongates (Protozoa, single-celled) were found at an average of 66,750 cells/liter. *Microcystis* sp. (Bloom-forming Cyanobacteria) was found at an average of 63,250 cells/liter. The high abundance of *Microcystis* sp. suggests declining water quality, as the presence of large amounts of cyanobacteria, such as *Microcystis* and *Aphanocapsa*, reflects eutrophication conditions that could lead to algal blooms (Table 1 and Fig.1).

Moderate Abundance Group (10,000–60,000 cells/liter): Testate Amoebae were found at an average of 59,000 cells/liter. *Phacus* sp. (Euglenoid) was found at an average of 8,500 cells/liter. *Lepocinclis* sp. was found at an average of 6,000 cells/liter. The presence of Testate Amoeba and other protozoa reflects conditions with high organic matter, which supports the life of decomposing organisms in an effective wastewater system (Table 1).

Low or Sporadic Abundance Group (≤5,000 cells/liter): Species such as *Spirostomum* sp., *Synedra* sp., *Diatoma* sp., *Spirulina* sp., *Didymocystis* sp., *Pseudoanabaena*, and others were found at very low levels, typically in small quantities or during specific periods. The presence of these species in low amounts or only during certain sampling events may indicate the changes in water quality at times (Table 1).

Table 1: The Abundances of Microbial Diversity within Water from Activated Sludge during July 2024 to March 2025

Species/Month	**1**	**2**	**3**	**4**	**Total Count (cells/liter)**
Aphanocapsa sp.	70,000	95,000	109,000	49,000	80,750
Coleps elongatus	88,000	100,000	39,000	40,000	66,750
Scenedesmus sp.	2,000	0	0	0	500
Microcystis sp.	0	95,000	109,000	49,000	63,250
Testate Amoebae	114,000	90,000	30,000	2,000	59,000
Purple sulfur bacteria	3,000	0	0	0	750
Phacus sp.	6,000	16,000	7,000	5,000	8,500
Navicula sp.	1,000	0	0	0	250
Cyclotella sp.	0	4,000	0	0	1,000
Rotifera	2,000	0	0	0	500
Epistylis	0	10,000	0	0	2,500
Vorticella microstoma	0	10,000	3,000	0	3,250
Pseudoanabaena	0	3,000	1,000	0	1,000
Spirostomum sp.	0	15,000	0	0	3,750
Daphnia sp.	0	1,000	0	0	250
Chlorella sp.	0	1,000	0	0	250
Oscillatoria sp.	0	1,000	0	0	250
Closteriopsis sp.	0	0	0	1,000	250
Euglena acus	0	0	0	1,000	250
Synedra sp.	0	4,000	3,000	1,000	2,000
Diatoma sp.	0	7,000	3,000	0	2,500
Lepocinclis sp.	0	15,000	1,000	8,000	6,000
Asplanchna sp.	0	1,000	0	0	250
Spirulina sp.	3,000	1,000	5,000	1,000	2,500
Didymocystis sp.	0	18,000	0	0	4,500
Tetrahedron sp.	0	1,000	0	0	250

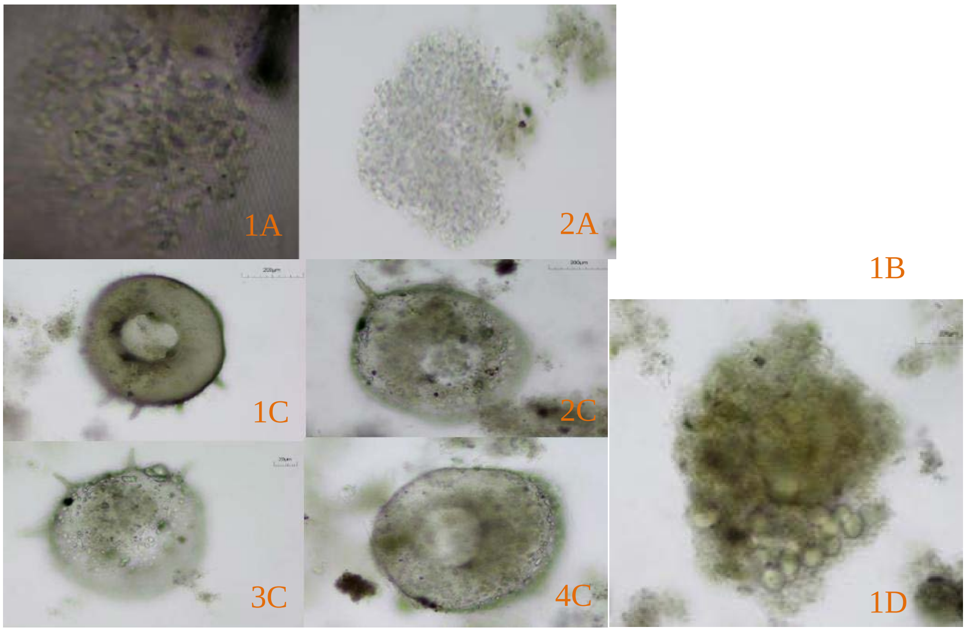

Figure 1: Microscopic appearances of abundance microbial species: *Aphanocapsa sp.* (1A-2A**)**; *Coleps elongatus* (1B); Testate Amoebae (1C-4C); *Microcystis sp.* (1D)

Discussion

Aphanocapsa sp. and *Microcystis* sp. showed a strong positive correlation with temperature and TDS (p<0.05), indicating that higher nutrient levels and warmer temperatures promote cyanobacterial growth, consistent with eutrophication (Smith et al., 1999). These cyanobacteria can lead to algal blooms, hypoxia, and toxin release, deteriorating water quality and impacting aquatic life (Paerl & Otten, 2013). While coliform and fecal coliform levels remained within Class 3 standards, their consistently high presence signals ongoing contamination and the need for continued monitoring. The moderate abundance of Testate Amoebae, *Phacus* sp., and *Spirostomum* sp. highlights the role of organic matter in supporting decomposers (Shannon & Wydoski, 1999). Low levels of species like *Spirostomum* sp. and *Synedra* sp. suggest sensitivity to water quality changes (Gómez et al., 2012). Seasonal temperature changes also influenced microbial dynamics, with warmer temperatures may promoting microbial growth (Armitage et al., 2016). These findings emphasize the need for effective nutrient management and regular monitoring to maintain water quality and system efficacy (EPA, 2017). Integrating eutrophication monitoring with wastewater treatment planning is crucial for managing water quality and preventing further degradation, particularly in urban water systems where nutrient overload is prevalent (Thongkao 2019, 2020).

Recommendations

1. Recommendations for the Application of Research Results

The research findings should be applied to optimize nutrient management in wastewater treatment systems, focusing on controlling harmful microbial growth, such as cyanobacteria, to improve water quality. Regular monitoring of key water quality parameters is essential for effective system management.

2. Recommendations for Future Research

Future research should explore the long-term effects of nutrient management strategies and investigate the role of specific microbial species in wastewater systems. Studies on the effectiveness of different treatment methods and broader geographical research will enhance understanding of microbial dynamics in various settings.

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