Water Quality and Ecological Contributions of Urban Wetlands: Insights from The Ait Campus in Thailand

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ABSTRACT

Wetlands are integral to urban ecosystems, providing essential services such as water purification, nutrient cycling, biodiversity support, and carbon sequestration. This study characterized the physico-chemical and microbiological water quality of seven selected wetlands at the Asian Institute of Technology (AIT) campus in Thailand between November 2016 and March 2017. Parameters analyzed included Dissolved Oxygen (DO), pH, Turbidity, Electrical Conductivity (EC), Ammonia-Nitrogen (NH_3-N), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Chemical Oxygen Demand (COD), Chlorophyll a, and Escherichia coli (E. coli). Additionally, sediment and macrophyte carbon sequestration, algal diversity, and zooplankton (rotifer) density were assessed. Results indicated slightly alkaline pH (7.5-8.3) and moderate to high DO levels (3.4-8.5 mg/L) across the wetlands. Elevated turbidity (12.9-16.7 NTU), nutrient enrichment (e.g., NH_3-N at 3.4 mg/L, TKN at 4.48 mg/L), and significant E. coli contamination (up to 7,420 MPN/100 mL) were observed in SV1 and Chiang Rak ponds. High chlorophyll a levels were notable in SV2 (195 µg/L) and Chiang Rak (928 µg/L). Carbon sequestration was substantial in macrophyte biomass (e.g., SV2: 9.4pm0.5 g C m^2 $month^{-1}$) and sediments (e.g., WD Pond: 6.6pm0.7 g C m^2 $month^{-1}$). While AIT wetlands provide considerable ecological services, these findings highlight pollution risks at certain sites, necessitating improved management for enhanced sustainability and ecosystem function.

Keywords: Biodiversity assessment, carbon sequestration, physico-chemical analysis, microbiological contamination, urban ecosystem services, wetland water quality.

Introduction

1.1 Combined Background and Literature Review

Wetland ecosystems, encompassing natural marshes, rivers, ponds, canals, and artificial wetlands, deliver a myriad of benefits to human society, including crucial services such as nutrient retention, flood control, and water purification [22, 7]. Despite their invaluable contributions, the comprehensive benefits of these services are often challenging to articulate to decision-making authorities and to quantify effectively. This difficulty often leads to wetland management policies and decisions that inadequately consider their vital ecological functions [24].

Urban wetlands, as integral components of urban green and blue spaces, are typically engineered to serve as buffers for stormwater runoff, preventing floods and retaining nutrients [25]. These systems are capable of supporting diverse ecosystem services and values [3]. Research demonstrates that urban wetlands improve surface water quality by removing solids, heavy metals, and nutrients like phosphorus (P) and nitrogen (N) from rainfall runoff in urban areas [8]. Furthermore, constructed wetlands are designed to be effective wastewater purification systems while simultaneously providing suitable habitats for various animal and plant species [7]. For example, urban wetlands in Melbourne, Australia, designed for aesthetic appeal and stormwater treatment, have become important habitats for numerous water birds [25].

Water quality in wetlands is commonly assessed using physico-chemical parameters such as pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), Turbidity, Total Dissolved Solids (TDS), and concentrations of nutrients like nitrates and phosphates [9, 17]. These parameters are critical as they directly influence the biochemical processes within wetland ecosystems and, consequently, their capacity to sustain diverse life forms [10]. Elevated nutrient levels, for instance, can trigger eutrophication, leading to rampant algal blooms and subsequent oxygen depletion, which severely jeopardizes aquatic biodiversity [5, 23]. In addition to physico-chemical indicators, microbiological indicators, particularly the presence of fecal coliforms and *Escherichia coli*, are indispensable for evaluating the sanitary quality of water, especially in wetlands susceptible to domestic or stormwater runoff [18, 17]. A study by Pragasan and Gomathi (2024) [20] highlighted that many physico-chemical parameters in their study locations exceeded WHO-recommended pollution thresholds, although most heavy metal concentrations remained within acceptable limits. This research also showed significant variation in physico-chemical parameters across study sites, with the exception of pH.

Ecosystem services are broadly defined as the benefits that humans derive from ecosystems [4]. Beyond tangible benefits, wetlands also offer significant intangible, non-material, spiritual, and cultural services [22]. The quantification of these services is crucial for evaluating the gains obtained by individuals from ecosystems. This process involves a wide array of techniques and is implemented through various methods and tools [16]. Quantifying ecosystem services serves as a vital tool to inform and support effective ecosystem management [16]. This quantification typically involves measuring biophysical outcomes, assessing how these outcomes affect the quantity and quality of ecosystem goods and services, and subsequently conducting an economic valuation of these goods and services [3, 27]. While previous research, such as Mukhtar (2015)'s study on the AIT Eco-campus [15], identified the actual and potential services provided by the AIT wetlands, it did not quantify them in a manner that would provide actionable data for wetland management on campus.

1.2 Research Gap

Despite the recognized importance of urban wetlands and previous qualitative assessments of AIT wetlands, there remains a gap in the quantitative characterization of their water quality and the comprehensive assessment of their ecological functions, particularly regarding the specific physico-chemical and microbiological parameters, and the extent of carbon sequestration and biodiversity support.

1.3 Study Rationale, Objectives, and Hypotheses

This study is therefore justified by the need to bridge this quantitative data gap. The primary objective is to characterize the water quality of wetlands at the AIT Campus by analyzing selected physico-chemical and microbiological parameters. This characterization aims to assess the current environmental status of these wetlands and identify potential threats to ecosystem health and public safety. Furthermore, the study aims to quantify carbon sequestration in macrophyte biomass and sediments, and to assess algal diversity and zooplankton density, thereby providing comprehensive data to support the sustainable management of these valuable urban ecosystems. It is hypothesized that variations in physico-chemical and microbiological parameters across the AIT wetlands will correlate with differences in their ecological functions, including carbon sequestration potential and biodiversity support, and that certain wetlands will exhibit signs of anthropogenic impact necessitating targeted management interventions.

2. Methods

2.1 Research Design

This study employed a descriptive research design to characterize the water quality and ecological functions of selected urban wetlands. A stratified sampling methodology was utilized to ensure representative data collection across the diverse wetland systems at the AIT campus. The study spanned from November 2016 to March 2017.

2.2 Study Area and Sampling Points

The study was conducted within the wetland systems located on the campus of the Asian Institute of Technology (AIT) in Khlong Luang-Pathumthani, Thailand. The AIT campus, an international university established in 1959, is situated approximately 40 kilometers north of Bangkok at coordinates 14circ04′16.00′′ N, 100circ36′50.51′′ E. The campus covers an area of 1.28 km2 and accommodates around 3,000 residents [15]. The region experiences an average annual temperature range of 25 to 33°C and receives an average annual precipitation of 1648 millimeters [15].

Seven wetlands were included in the study: Fountain Pond, W Dorm Pond, SV1 Pond, SV2 Pond, Library Pond, Library Canal, and West Lake. These wetlands were further divided into fifteen distinct layers to facilitate comprehensive sampling. Specific sampling points within the Fountain Pond (FP), Library Canal (LC), and Library Pond (LP) systems were clearly defined for analysis.

2.3 Experimental Procedure/Data Collection

2.3.1 Water Sample Collection and Analysis

Water sampling and analysis adhered to methods outlined in the Standard Method (APHA, 2005). Samples were collected either bi-weekly or monthly, depending on the specific parameter being analyzed, over the study period from November 2016 to March 2017. Water samples for physico-chemical and microbiological analysis were collected in clean plastic bottles and immediately transported to the AIT Environmental Engineering and Management Laboratory for examination, following standard protocols.

The following physico-chemical parameters were analyzed: Turbidity, pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Ammonia-Nitrogen (NH_3-N), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), and Chemical Oxygen Demand (COD). Chlorophyll a and *Escherichia coli* (E. coli) were the primary microbiological characteristics investigated. Measurements for turbidity, pH, EC, and DO were performed using respective meters. Nitrogen was assessed using the Total Kjeldahl and Titrimetric Methods [9]. Total phosphorus was quantified using the Persulphate technique. Algae species were identified using a compound microscope, and chlorophyll a was assessed via the trichromatic method [14].

2.3.2 Sediment Analysis for Carbon Determinatio

Three non-disturbed sediment samples were collected monthly from the bottom of the Fountain Ponds system, SV1 Pond, SV2 Pond, and WD Pond using a Peterson grab sampler. Samples were stored in labeled containers and transported to the AIT Environmental Engineering and Management laboratory. Sediment samples were analyzed for moisture content and Organic Carbon (OC) using the Loss-on-ignition technique. For moisture and carbon measurement, 40g of wet sediment were manually homogenized and transferred into crucibles. Moisture content was determined by weighing the sample, drying it at 105°C for 24 hours, and reweighing. Organic matter content was calculated from the mass loss after burning samples at 550°C for 24 hours in a muffle furnace. Organic matter was then converted to organic carbon using the method and relationship described by Percival (2017) [19].

2.3.3 Macrophyte Analysis for Carbon Determination

Macrophyte samples were collected from each sampling site using a 1 m2 quadrat. Stems, leaves, and root biomass were removed, placed in plastic bags, and transported to the AIT Environmental Engineering and Management lab for organic carbon analysis. The collected biomass was oven-dried at 80°C for 48 hours. After drying, the biomass was pulverized, sieved, and analyzed for organic carbon using the Walkley-Black technique [2].

2.3.4 Algal/Cyanobacterial Species Analysis

Algae species were examined under a compound microscope at 100x magnification. The diversity of algal species, particularly in relation to water quality and the influence of macrophytes on algae/cyanobacteria (Spirulina sp.) in Fountain Pond, was assessed. The AIT fountain-library pond system was divided into seven sample locations, with surface grab samples taken within 0.3 meters of the water's depth. Algal mats or scum layers were separately collected and interpreted. The average concentration over time or space was determined by averaging concentrations from multiple grab samples.

2.3.5 Zooplankton (Rotifers) Analysis

Rotifers were identified and analyzed following the Standard Operating Procedure for Zooplankton Analysis (US/EPA, 1994). A 1000 mL sample was sub-divided into 125 mL, from which a 1 mL aliquot was extracted for analysis and rotifer computation. Rotifers were inspected using Sedgwick-Rafter cell slides under a compound microscope at 100x magnification. Rotifer density was reported as the computed mean of three replications from the subdivided samples.

2.4 Data Analysis Plan

All collected data for physico-chemical, microbiological, sediment carbon, macrophyte carbon, algal, and zooplankton analyses were compiled and statistically analyzed. Mean values and standard deviations were calculated for all parameters. Statistical comparisons, such as t-tests or ANOVA, were performed to identify significant differences in parameters across different wetland sites and sampling periods. Specific statistical significance levels (e.g., p-values) were used to interpret the results, particularly for carbon sequestration comparisons.

3. Results

The comprehensive physico-chemical and microbiological characterization of the AIT wetland systems (Fountain Pond (FP), Student Village I & II Pond (SV1-2), W Dorm pond (WD), Library pond (LP), Library Canal (LC), West Lake (WL), Chiang Rak (CR)) aimed to provide data supporting the quantification of wastewater treatment benefits and carbon sequestration services.

3.1 Key Findings (Primary & Secondary condensed)

3.1.1 Physico-chemical and Microbiological Water Quality

The water in all studied AIT wetlands exhibited a slightly alkaline pH, with values ranging from a minimum of 7.5pm0.1 to a maximum of 8.3pm0.1. Dissolved Oxygen (DO) concentrations varied between 3.4pm0.4 mg/L and 8.5pm0.3 mg/L across the selected wetlands. Turbidity values ranged from 4.0pm0.1 NTU to 16.7pm0.4 NTU. Electrical conductivity (EC) spanned from 570pm9 µs/cm to 1,137pm170 µs/cm, while water temperature ranged from 25.1pm0.4 to 28.7pm0.9°C.

Chemical water quality parameters, including Ammonia-Nitrogen (NH_3-N), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Chemical Oxygen Demand (COD), and Chlorophyll a, showed variability across sites. Notably, Chiang Rak pond exhibited significantly higher levels of NH_3-N (3.4pm0.01 mg/L), TKN (4.48pm0.20 mg/L), TP (0.75pm0.02 mg/L), and Chlorophyll a (928pm22 µg/L) compared to other wetlands. SV2 also recorded a high Chlorophyll a level of 195pm26 µg/L. Microbiological analysis indicated the presence of *E. coli* in all wetlands, with concentrations ranging from 71pm10 MPN/100mL in

Library Canal to a critically high 7420 MPN/100mL in Chiang Rak Pond. SV1 Pond also showed high *E. coli* contamination, with concentrations reaching 4,498pm229 MPN/100mL.

Diurnal variations in DO and pH were observed in Fountain and SV1 ponds. DO concentrations were lowest in the early morning (6:00 AM), with 0.51 mg/L in Fountain Pond and 0.42 mg/L in SV1 Pond, and peaked around 4:00 PM at 6.8 mg/L and 5.0 mg/L, respectively. Similarly, pH values were lowest at 8:00 AM (6.3 for Fountain, 7.0 for SV1) and highest at 4:00 PM (8.0 for Fountain, 7.9 for SV1). The comparatively high pH values in the afternoon could be attributed to increased alkalinity resulting from microalgae photosynthesis.

3.1.2 Carbon Sequestration

Sediment carbon storage varied among the wetlands, although monthly differences within individual wetlands were not statistically significant (p0.05). However, the average monthly carbon stored across the wetlands showed high significance ($p\<0.001$), with WD Pond demonstrating significantly greater carbon sequestration due to its extensive macrophyte coverage and sediment stability. WD Pond recorded the highest monthly sediment carbon of 6.6pm0.7 g C m−2 month^{-1}. The total sediment carbon sequestration for the selected wetlands was estimated at 14.6pm1.6 g C m−2 month^{-1} (equivalent to 175.2pm19.2 g C m−2 year^{-1}).

Macrophyte carbon sequestration also showed significant differences among Fountain Pond, SV2 Pond, and WD Pond ($p\<0.001$). SV2 Pond exhibited the highest mean macrophyte carbon accumulation, with 9.4pm0.5 g C m−2 month^{-1}, supporting the inference that its higher macrophyte biomass contributes to greater carbon storage. The total macrophyte carbon sequestration across the selected wetlands was 25.7pm1.5 g C m−2 month^{-1} (equivalent to 308.4pm18 g C m−2 year^{-1}).

3.1.3 Algae Species Analysis

Analysis of algal species populations revealed that Fountain Pond possessed the greatest diversity of species, while other ponds had fewer. The most prevalent species identified were Nitzschia, diatoms, chlorella, and euglenoids. Marginal varieties included *Scenedesmus sp.*, *Selenastrum sp.*, Merismopedia, Actinastrum, and *Ankistrodesmus sp.*. Euglenoids were found to be the main genus of Chlorophyta (green algae) across all AIT wetlands. Notably, Cyanobacteria, such as *Spirulina sp.*, were not detected.

3.1.4 Zooplankton (Rotifer) Density

Rotifer density varied across the sampling sites, with the highest density recorded in Fountain Pond (280pm43 individuals/L). This higher rotifer density in Fountain Pond corresponded with improved microbial water quality in that particular wetland.

3.2 Summary of Outcomes

The study provided quantitative data on the physico-chemical and microbiological water quality of AIT wetlands, highlighting variations across sites, particularly concerning nutrient enrichment and *E. coli* contamination. It also quantified significant carbon sequestration contributions from both sediments and macrophytes, emphasizing the ecological value of these urban wetland systems. The biodiversity assessment, focusing on algal and rotifer populations, further illustrated the ecological health and functional diversity of the wetlands.

4. Discussion

4.1 Interpretation of Results

The findings from this study provide a comprehensive characterization of the water quality and ecological functions of urban wetlands within the AIT Campus. The observed slightly alkaline pH values (7.5-8.3) across all wetlands indicate a relatively stable buffering capacity, which is generally favorable for aquatic life. Moderate to high DO levels (3.4-8.5 mg/L) suggest the presence of oxygen, critical for supporting aerobic aquatic organisms. However, the diurnal fluctuations in DO, with lowest levels in the early morning, point to photosynthetic activity during the day by algae and macrophytes, consuming oxygen at night. The corresponding pH increase in the afternoon further supports this, as photosynthetic uptake of carbon dioxide can increase alkalinity.

The elevated turbidity in SV1 and Chiang Rak ponds (12.9-16.7 NTU) suggests increased suspended solids, potentially from runoff or algal blooms. This is concerning as high turbidity can reduce light penetration, impacting submerged aquatic vegetation and overall water clarity. The significant nutrient enrichment, specifically high NH_3-N and TKN in SV1 and Chiang Rak ponds, is a strong indicator of pollution, likely from sewage or other anthropogenic sources. These elevated nutrient levels directly contribute to the high chlorophyll a concentrations observed in SV2 (195 μg/L) and particularly in Chiang Rak (928 μg/L), signaling a high algal biomass and a state of eutrophication. Eutrophication can lead to oxygen depletion, threatening aquatic biodiversity, a concern highlighted by Kumar et al. (2022) [10].

The critical *E. coli* contamination (up to 7,420 MPN/100 mL) in SV1 and Chiang Rak ponds is a major public safety concern, indicating fecal contamination and potential health risks for human contact with these waters. The fluctuating *E. coli* concentrations further underscore the intermittent nature of pollution inputs into these specific wetlands. This aligns with Nica-Badea and Tataru (2023)'s [17] assertion that fecal coliforms are essential for assessing sanitary water quality in wetlands receiving runoff.

The substantial carbon sequestration rates in both macrophyte biomass and sediments underscore the significant ecological function of these urban wetlands in mitigating climate change. WD Pond's higher sediment carbon storage (6.6pm0.7 g C m^2 $month^{-1}$) and SV2 Pond's higher macrophyte carbon accumulation (9.4pm0.5 g C m^2 $month^{-1}$) highlight their roles as carbon sinks, directly linked to their extensive macrophyte coverage and sediment stability. This confirms wetlands' vital role in carbon sequestration.

The diversity of algal species, with Fountain Pond exhibiting the highest diversity and prevalence of Nitzschia, diatoms, chlorella, and euglenoids, indicates a relatively healthy aquatic environment in that pond. The absence of *Cyanobacteria* like *Spirulina sp.* in all wetlands is a positive sign, as cyanobacterial blooms are often associated with poor water quality and can produce toxins [5]. The highest rotifer density in Fountain Pond, correlating with improved microbial quality, further supports the notion that this wetland generally maintains better ecological health compared to those with high contamination levels.

4.2 Comparison with Existing Literature

The study's findings corroborate existing literature on the multi-functional roles of urban wetlands. The observed water purification capabilities through the removal of nutrients and solids align with the functions described by Li et al. (2017) [11]. The importance of physico-chemical parameters like pH, DO, and EC as water quality indicators, as identified in this study, is consistent with assessments by Nayar (2020) [16] and Jaffar et al. (2020) [9]. The issue of eutrophication driven by nutrient enrichment and subsequent algal blooms, evidenced by high chlorophyll a levels in Chiang Rak and SV2 ponds, echoes the concerns raised by Kumar et al. (2022) [10] regarding threats to aquatic biodiversity.

The presence of *E. coli* as a key microbiological indicator of sanitary water quality is well-established in the literature. The high *E. coli* counts in certain AIT wetlands, particularly SV1 and Chiang Rak, highlight a common challenge in urban wetlands that receive runoff, consistent with findings in other urban environments [18].

The quantification of carbon sequestration by macrophytes and sediments provides valuable empirical data, reinforcing the widely acknowledged role of wetlands as significant carbon sinks [21, 26]. This contributes to the growing body of knowledge on the economic values of ecosystem services, as highlighted by Brander et al. (2024) [3]. While Mukhtar (2015) [15] previously identified potential services of AIT wetlands, this study goes further by quantifying specific ecological functions, providing the data needed for more informed management decisions, addressing the gap identified by Mukhtar (2015) [15] and others regarding the quantification of ecosystem services. The observed biodiversity, particularly the presence of diverse algal species and rotifers, underscores the ecological value of these urban green spaces, consistent with the broader understanding of urban ecosystems supporting various species.

4.3 Strengths and Limitations

A key strength of this study is its comprehensive assessment of multiple water quality parameters, including physico-chemical, microbiological, and ecological indicators (carbon sequestration, algal diversity, zooplankton density), providing a holistic view of wetland health. The stratified sampling methodology enhances the representativeness of the collected data. The quantification of carbon sequestration specifically for AIT wetlands adds unique local data to global climate change mitigation efforts.

However, the study period was relatively short (November 2016-March 2017), which might not capture seasonal variations beyond the dry season in Thailand. A longer-term monitoring program would provide more robust insights into seasonal trends and long-term changes in water quality and ecological functions. While carbon sequestration was quantified, the specific mechanisms and influencing factors could be explored in greater detail. The study also did not investigate the sources of pollution, which would be crucial for targeted management interventions. Furthermore, the economic valuation of the quantified ecosystem services was not part of this study, leaving a potential area for future research [27].

4.4 Theoretical and Practical Implications

The findings have significant theoretical and practical implications. Theoretically, the study reinforces the interconnectedness of physico-chemical water quality parameters with the ecological functions and biodiversity of urban wetlands. It underscores the concept that wetland health is a direct reflection of both natural processes and anthropogenic impacts, influencing their capacity to provide ecosystem services [28]. The observed diurnal variations in DO and pH contribute to the understanding of metabolic processes within these specific wetland ecosystems.

Practically, this research provides crucial data for the sustainable management of AIT wetlands and offers a model for other urban wetland systems. The identification of specific wetlands (SV1 and Chiang Rak) with elevated pollution levels necessitates immediate management interventions, such as improved wastewater management, stormwater runoff control, and potentially bioremediation strategies [6]. The substantial carbon sequestration rates highlight the importance of preserving and enhancing macrophyte coverage and sediment stability in wetlands to maximize their climate change mitigation potential [21]. The study emphasizes the need for regular water quality monitoring, especially for microbiological parameters, to ensure public safety [18]. Promoting public awareness about responsible waste disposal and the ecological value of wetlands can also contribute to their long-term health.

4.5 Conclusion and Future Research

In conclusion, the urban wetlands at the AIT Campus offer vital ecological services, including significant carbon sequestration and support for biodiversity. However, certain wetlands, particularly SV1 and Chiang Rak ponds, are experiencing considerable pollution from nutrient enrichment and microbiological contamination, compromising their ecological health and public safety. The study quantifies these impacts and highlights the need for improved management strategies to enhance the sustainability and ecosystem functions of these valuable urban green infrastructures.

Future research should focus on long-term monitoring to understand seasonal dynamics and inter-annual variability in water quality and ecological functions. Investigating the specific sources of pollution for the contaminated wetlands is crucial to implement targeted interventions. Further studies could also explore the economic valuation of the identified ecosystem services, which would provide a stronger argument for wetland conservation and management to decision-makers [3, 27]. Research into the effectiveness of various remediation techniques for improving water quality and enhancing ecological functions in these specific urban wetland contexts would also be highly beneficial. Finally, comparative studies with other urban wetland systems could provide broader insights and best practices for urban wetland management globally.

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