



Comprehensive Assessment of Surface Water Quality in Ban Pru Toei Community Forest: Physical, Chemical, and Biological Parameters

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Abstract: This study conducted an integrated assessment of surface water quality in Ban Pru Toei Community Forest (42.56 ha), Bang Khan District, Nakhon Si Thammarat Province, Thailand. Water samples were collected in triplicate from five monitoring stations along a 3.05 km transect during the dry season of January–March 2023. Mean physical parameters across all stations were: temperature $26.13 \pm 0.96^{\circ}\text{C}$ (range: $25.00\text{--}28.00^{\circ}\text{C}$), total dissolved solids (TDS) $11.60 \pm 0.13\text{ mg/L}$ (range: $7.56\text{--}18.40\text{ mg/L}$), and pH 6.77 ± 0.13 (range: $6.15\text{--}7.05$)—all compliant with Thailand's Pollution Control Department Class 1 standards. Mean dissolved oxygen (DO) was $4.36 \pm 0.10\text{ mg/L}$ (range: $3.23\text{--}5.60\text{ mg/L}$), with Station 2 (Waterfall) recording the highest DO ($4.75 \pm 0.07\text{ mg/L}$) and Station 5 (Canal) the lowest ($3.90 \pm 0.10\text{ mg/L}$). Mean water hardness was $14.65 \pm 0.07\text{ mg/L}$ (range: $8.13\text{--}25.03\text{ mg/L}$), well below the 300 mg/L Class 1 threshold. Biological assessment identified 22 families across 10 orders of aquatic macroinvertebrates; Odonata (5 families) was the most diverse order, followed by Ephemeroptera and Coleoptera (3 families each). Pollution-sensitive taxa (*Perlidae*, *Heptageniidae*, *Ephemeridae*) were present at Stations 2–5 but absent from Station 1, which was dominated by moderately clean water indicators (*Filopaludina sumatrensis*, 91.8% of individuals). This spatial distribution confirmed Class 1/2 ecological status at Stations 2 and 3, Class 2 at Stations 1 and 4, and Class 3 at Station 5. A modified Water Quality Index (WQI; formula: $0.3 \times \text{Physical} + 0.3 \times \text{Chemical} + 0.4 \times \text{Biological}$) scored Stations 2 and 3 highest (86.7/100) and Station 5 lowest (68.3/100). These findings establish quantitative baseline data for the dry season, supporting adaptive management and community-based conservation strategies for this ecologically significant watershed. Year-round monitoring spanning the wet season is recommended to provide a complete annual baseline.

Keywords: Water quality; aquatic macroinvertebrates; bioindicators; community forest; dissolved oxygen

1. Introduction

Water is a fundamental resource for all living organisms, essential for various physiological processes and ecosystem functions. The quality of water resources directly impacts human health, agricultural productivity, and ecological sustainability [1]. Despite water covering approximately 71% of Earth's surface, only 1% is available as freshwater for human consumption and ecosystem support [2]. With increasing anthropogenic pressures on freshwater resources, maintaining water quality has become a critical global challenge. Water quality assessment involves systematic evaluation of physical, chemical, and biological parameters to determine the suitability of water for various uses and its ecological status [3]. Physical parameters such as temperature and total dissolved solids determine water's basic properties. In contrast, chemical parameters such as pH, hardness, and dissolved oxygen indicate pollution levels and the support of aquatic life. Biological assessment, particularly using aquatic macroinvertebrates as bioindicators, offers insights into long-term environmental conditions that physicochemical measurements alone might not reveal [4].

Aquatic macroinvertebrates have become indicators of water quality due to their diverse habitat preferences, varying tolerance to pollution, and relatively long life cycles [5]. Different species exhibit specific sensitivity thresholds to environmental stressors, making their community structure an excellent reflection of water quality [6]. Species composition and abundance patterns can indicate pollution impacts over extended periods, providing a more comprehensive picture than instantaneous chemical measurements [7]. Ban Pru Toei Community Forest, located in Bang Khan Sub-district, Bang Khan District, Nakhon Si Thammarat Province, represents a significant aquatic ecosystem in southern Thailand. Covering approximately 266 rai (42.56 ha), this community forest is a moist evergreen forest with waterlogged depressions and substantial accumulation of soil organic matter [8]. The forest features natural springs that feed into local water bodies, creating a network of freshwater systems that support diverse flora and fauna. The predominant vegetation includes teow (*Shorea roxburghii*), baawm maamued (*Quercus kerrii*), wild guava (*Psidium guajava*), and Asoka trees (*Saraca asoca*), all of which contribute to the forest's ecosystem services. The presence of the royal crab (*Phricotelphusa sirindhorn*) is a key ecological indicator [8]. Community forests in Thailand operate under a co-management model in which local communities and government agencies collaborate to manage resources sustainably [9].

Despite its ecological and community significance, Ban Pru Toei Community Forest has not previously undergone an integrated physicochemical and biological water-quality assessment. Prior studies in Nakhon Si Thammarat Province have focused primarily on coastal and agricultural waterways, leaving inland community forest water systems largely uncharacterized. This research gap limits local communities that depend on these water sources for domestic and agricultural use from making informed management decisions. The present research aims to comprehensively assess surface water quality in Ban Pru Toei Community Forest through integrated physical, chemical, and biological analyses. Specifically, this study seeks to: (1) determine the physical and chemical characteristics of surface water at five monitoring stations; (2) inventory aquatic macroinvertebrate communities as biological indicators; (3) evaluate overall water quality status against Thailand's national surface water standards; and (4) establish baseline data for future monitoring and adaptive conservation management.

2. Materials and methods

2.1 Study area

The study was conducted in Ban Pru Toei Community Forest in Bang Khan Sub-district, Bang Khan District, Nakhon Si Thammarat Province, southern Thailand. The community forest encompasses approximately 266 rai (42.56 hectares) and is characterized by a moist evergreen forest with waterlogged depressions and significant accumulation of soil organic matter. Five sampling stations were established along a 3.05-kilometer stretch of the water system as point 1 (Upstream): Located at the headwaters (UTM coordinates: E = 545812, N = 887773), point 2 (Waterfall): Located at a natural waterfall formation (UTM coordinates: E = 546090, N = 887990), point 3 (Dam Head): Positioned at the upstream section of a small dam (UTM coordinates: E = 546650, N = 887686), point 4 (Dam Tail): Located at the downstream section of the dam (UTM coordinates: E = 546879, N = 887605), and point 5 (Pru Toei Canal): Situated along the Pru Toei Canal

(UTM coordinates: E = 548215, N = 889650) (Fig. 1). These sampling points were selected to represent different hydrological conditions within the forest ecosystem, including headwaters, flowing streams, impounded water, and canal systems. The geographic distribution enables comprehensive water-quality evaluation throughout the watershed.

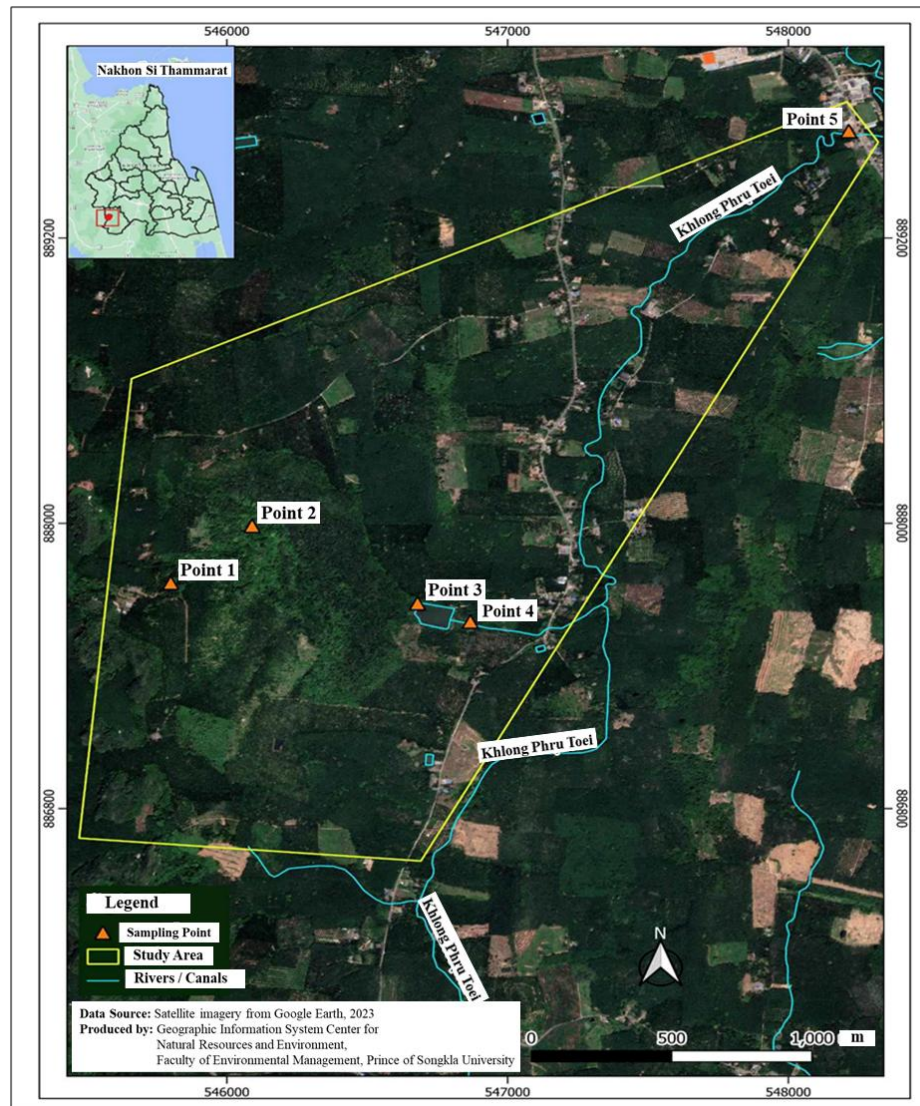


Figure 1. Water sampling point in the Ban Phru Toei community forest area.

2.2 Sampling Protocol and Duration

Water samples were collected monthly over three months from January to March 2023. This timeframe corresponds to the dry season in southern Thailand, when water quality issues are typically more pronounced due to reduced flow and the potential for pollutant concentration. This study, therefore, represents a dry-season baseline; wet-season conditions are not captured and should be addressed in future monitoring campaigns. Water samples were collected in triplicate at each sampling station to ensure statistical reliability. Temperature was measured in situ using a calibrated mercury thermometer ($\pm 0.1^\circ\text{C}$). Water samples for TDS and pH analysis were collected in clean 1-liter polyethylene bottles rinsed three times with sample water. For dissolved oxygen (DO) analysis, specialized 300 mL BOD bottles were used. Oxygen fixation reagents (manganous sulfate and alkali-iodide-azide) were added to the BOD bottles immediately upon collection at the sampling site, following Standard Methods 4500-O C for the azide modification of the Winkler method. Fixed samples were transported to the laboratory on ice ($\leq 4^\circ\text{C}$) and titrated within 6 hours.

of collection. Aquatic macroinvertebrates were collected using standardized kick-sampling techniques with a D-frame net (500 μm mesh), with three 1-meter sweeps across different microhabitats (leaf litter, submerged vegetation, open water) per station. Organisms were preserved in 70% ethanol for laboratory identification.

2.3 Physical Parameters Measurement Techniques

Temperature was measured in situ using a calibrated mercury thermometer ($\pm 0.1^\circ\text{C}$ precision) at mid-depth. TDS was determined using a Conductivity Meter LE703 (Mettler Toledo). pH was measured using an OHAUS ST2100F pH meter calibrated with pH 4.0, 7.0, and 10.0 buffer solutions. All field instruments were calibrated in accordance with the manufacturers' specifications. Triplicate measurements were taken at each station per month and averaged. For temperature, the three-monthly readings per station were averaged; the overall mean $\pm$ SD reported reflects variability across both stations and months. Physical parameter values were normalized against Thailand's Class 2 surface water quality standards using a ratio-based formula (observed value / standard threshold $\times$ 100) to compute the WQI Physical Score.

2.4 Chemical Parameters Analytical Methods

Water hardness was determined using the EDTA Titrimetric Method (Standard Methods 2340C; APHA [10]) with Eriochrome Black T as the visual endpoint indicator. Dissolved oxygen was analyzed using the azide modification of the Winkler method (Standard Methods 4500-O C). As noted in 2.2, oxygen fixation was performed in the field immediately upon sample collection. The method's precision is ± 0.1 mg/L. All chemical analyses were performed in triplicate. Quality control measures included analysis of blanks, spikes, and certified reference materials with each batch of samples.

2.5 Biological Assessment Using Aquatic Macroinvertebrates

Biological assessment was conducted using aquatic macroinvertebrates as bioindicators, following the methodology of Kanjanavanit [11]. Family-level identification was selected because the Thai bioindication framework of Kanjanavanit [11], on which the five-tier pollution tolerance classification is based, is structured at the family level, and this is also consistent with standard practice in Thai freshwater biomonitoring studies [9]. Organisms were identified at the family level using a stereomicroscope (10–40 $\times$ magnification) and taxonomic keys for Thai freshwater fauna. Families were classified into five pollution tolerance categories: Very Clean Water Indicators (e.g., Perlidae, Heptageniidae), Clean Water Indicators (e.g., Odonata families, Corydalidae), Moderately Clean Water Indicators (e.g., Gerridae, Baetidae), Dirty Water Indicators (e.g., Chironomidae), and Non-indicator Taxa (e.g., Potamidae). It is acknowledged that three 1-meter sweeps per station represent a minimum effort that may underestimate the richness of rare or patchily distributed taxa; comparisons of absolute abundance across stations should be interpreted with this caveat.

2.6 Statistical Analysis

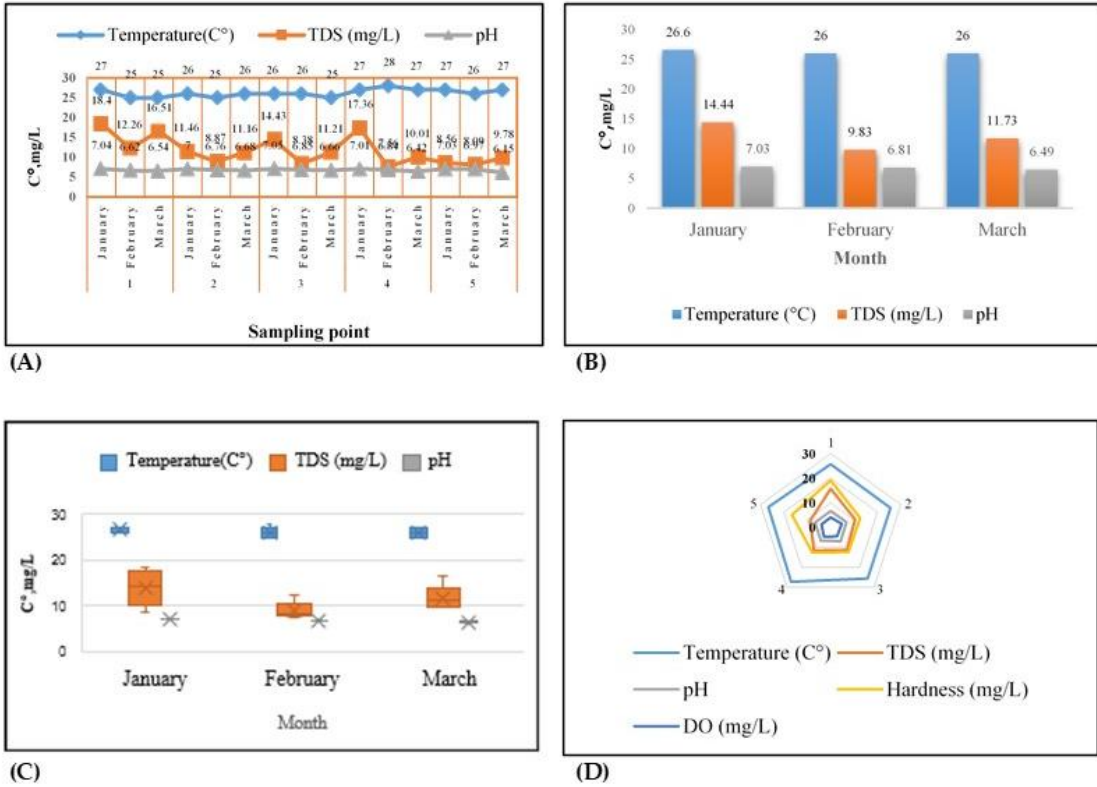
Descriptive statistics (mean $\pm$ SD) were calculated for all water quality parameters. The Pearson correlation coefficient (r) was used to examine the relationship between hardness and dissolved oxygen, with statistical significance assessed at $\alpha = 0.05$. Statistical analyses were performed using Microsoft Excel (version 2021). Water Quality Index scores were computed using the weighted formula, with each parameter normalized against Thailand Class 2 surface water quality standards.

3. Results and Discussion

3.1 Physical Water Quality Analysis

Water temperature across the five stations ranged from 25.00°C to 28.00°C during January–March 2023, with an overall mean of $26.13 \pm 0.96^\circ\text{C}$ (Fig. 2). Station 4 (Dam Tail) exhibited the highest mean temperature ($27.33 \pm 0.58^\circ\text{C}$), presumably attributable to its location downstream of the dam, where reduced water velocity and presumably increased solar exposure promote warming; direct measurements of flow velocity and canopy cover were not obtained in this study. All recorded temperatures fall within the optimal range for tropical freshwater ecosystems (25 – 30°C) and comply with Thailand's surface water quality standards [12]. TDS concentrations varied from 7.56 ± 0.04 mg/L (Station 4, February) to 18.40 ± 0.26 mg/L (Station 1, January), with an overall mean of 11.60 ± 0.13 mg/L (Fig. 2). The highest TDS values occurred in

January, reflecting reduced dilution during the dry season. All TDS values were well below the Class 1 threshold of 500 mg/L [12], consistent with a forested watershed having minimal anthropogenic inputs and very low dissolved mineral content [1]. pH values ranged from 6.15 ± 0.17 (Station 5, March) to 7.05 ± 0.07 (Station 3, January), with an overall mean of 6.77 ± 0.13 (Figure 2). A temporal decline was observed from January (mean 7.03) to March (mean 6.49), attributed to the progressive decomposition of organic material, which released humic acids during the dry season. All pH values fall within the acceptable range (5.0–9.0) for surface water standards in Thailand [12].



Sampling Point	Month	Temperature_norm	TDS_norm	pH_norm
1	January	0.67	1	0.99
	February	0	0.43	0.52
	March	0	0.83	0.43
2	January	0.33	0.36	0.94
	February	0	0.12	0.68
	March	0.33	0.33	0.59
3	January	0.33	0.64	1
	February	0.33	0.08	0.78
	March	0	0.34	0.57
4	January	0.67	0.91	0.96
	February	1	0	0.77
	March	0.67	0.23	0.3
5	January	0.67	0.09	0.98
	February	0.33	0.05	0.91
	March	0.67	0.21	0

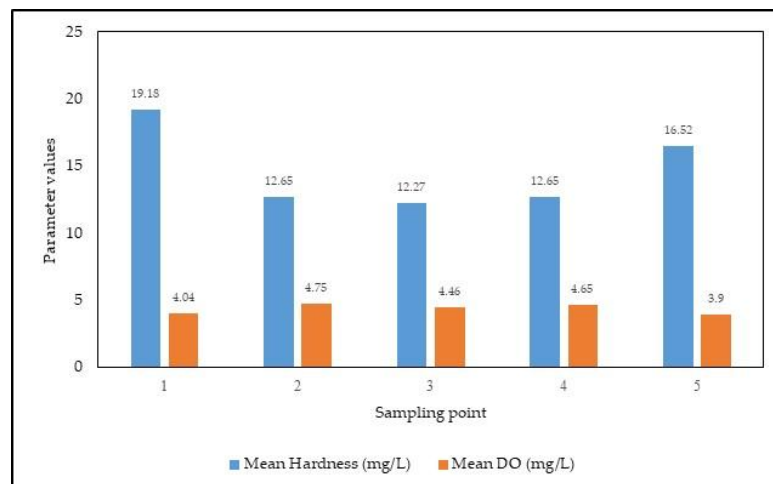
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Figures 2. Physical Water Quality Parameters at Five Sampling Points in Ban Pru Toei Community Forest (January-March 2023)

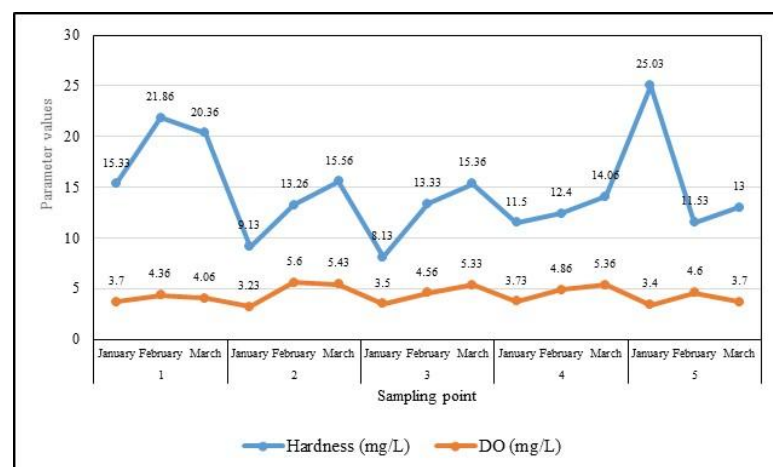
3.2 Chemical water quality analysis

Water hardness varied from 8.13 ± 0.11 mg/L (Station 3, January) to 25.03 ± 0.05 mg/L (Station 5, January), with an overall mean of 14.65 ± 0.07 mg/L (Fig. 3 and Fig. 6). All values are classified as 'soft' water (0–60 mg/L as CaCO_3) and are well below the Class 1 upper limit of 300 mg/L [12]. The elevated hardness at Station 5 in January likely reflects localized geological features or anthropogenic inputs from adjacent agricultural areas at the forest periphery. DO concentrations ranged from 3.23 ± 0.05 mg/L (Station 2, January) to 5.60 ± 0.10 mg/L (Station 2, February), with an overall mean of 4.36 ± 0.10 mg/L (Fig. 4 and Fig. 5). Station 2

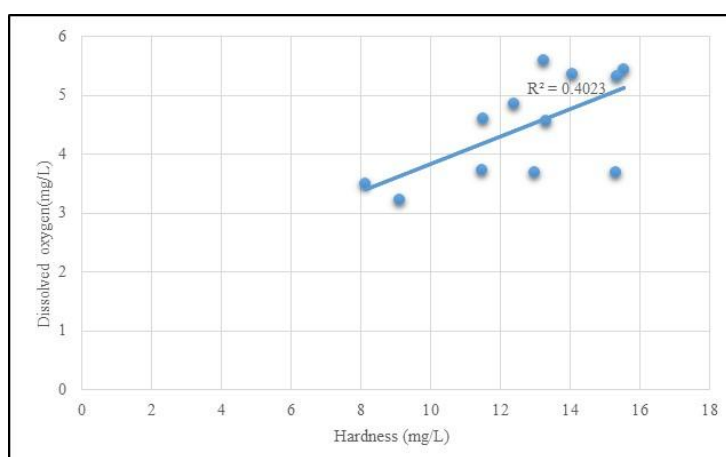
(Waterfall) exhibited the highest mean DO (4.75 ± 0.07 mg/L) due to enhanced aeration from turbulent flow [6]. Station 5 exhibited the lowest (3.90 ± 0.10 mg/L). The low January DO values at all stations reflect typical dry-season conditions: higher water temperatures reduce oxygen solubility, and reduced flow limits aeration. Under Thailand's standards [12], most stations qualified as Class 2 waters in February and March ($\text{DO} \geq 4.0$ mg/L), while January values and Station 5 consistently met Class 3 criteria ($\text{DO} \geq 2.0$ mg/L). The relationship between hardness and DO across sampling points showed a positive correlation ($r = +0.63$, $p = 0.012$, 95% CI: 0.14 to 0.87, $n = 15$), with higher hardness values associated with higher DO concentrations. Station 2 (Waterfall), which combines moderate hardness with the highest DO due to turbulent aeration, anchors this positive trend. Station 5, despite its high hardness (25.03 mg/L in January), exhibits the lowest DO, suggesting that other factors (organic enrichment, reduced flow) override the hardness–DO covariation at this downstream canal station. The correlation should be interpreted cautiously, given the limited sample size ($n = 15$). It should be noted that the present study did not include analysis of heavy metal concentrations (e.g., Zn, Pb, Cu, Cr) in either water or sediment. Given that Station 5 (Pru Toei Canal) is situated adjacent to smallholder rice paddies and rubber plantations, trace metal inputs from agrochemicals and runoff represent a plausible but unquantified risk. Alburo and Villegas [13] documented significant downstream exceedances of Cu and Cr threshold concentrations — and exceedances of Zn limits at all stations — in the Lahug River, a peri-urban waterway with comparable land-use pressures in Metro Cebu, Philippines. A parallel heavy metal assessment for Station 5 of Ban Pru Toei is therefore recommended as a priority for future monitoring.



Figures 3. Comparing Mean Values of Hardness and Dissolved Oxygen Across Sampling Points



Figures 4. Chemical Water Quality Parameters at Five Sampling Points in Ban Pru Toei Community Forest (January–March 2023)



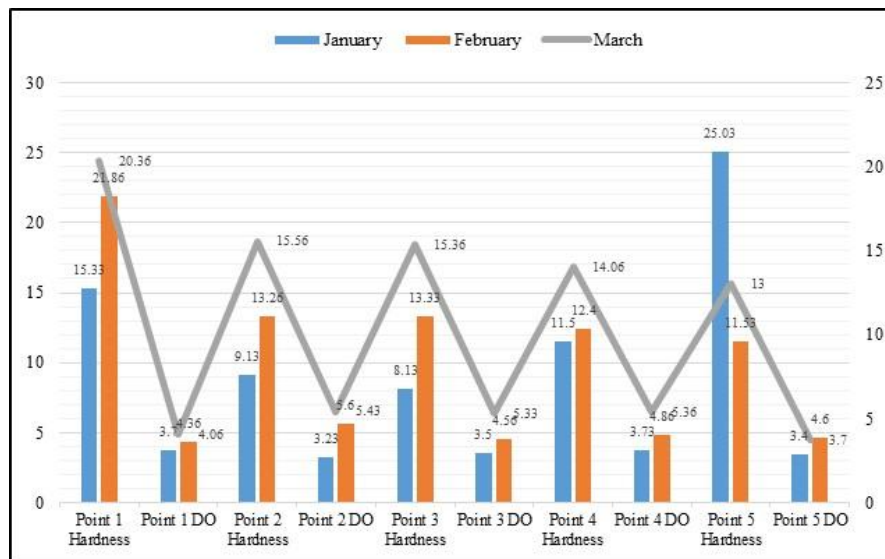
Figures 5. The relationship between hardness and dissolved oxygen, with data points coded by sampling location

3.3 Biological Water Quality Assessment

The biological assessment identified 22 families across 10 orders of aquatic macroinvertebrates. Odonata was the most diverse order (5 families), followed by Ephemeroptera and Coleoptera (3 families each). Complete abundance data by family, station, and month are provided in Supplementary, which also reports Shannon diversity indices (H') ranging from 0.89 at Station 1 to 2.31 at Station 5. The observed taxonomic richness (22 families) is comparable to similar forested watersheds in southern Thailand [9]. Based on established bioindicator classifications [11], families were assigned to five pollution tolerance tiers. *Phricotelphusa sirindhorn* (Potamidae) was classified as a non-indicator taxon per the standard Thai bioindication framework; however, as an endemic habitat specialist with restricted distributional requirements, its presence may have broader ecological indicator value and warrant further investigation. The predominance of clean and moderately clean water indicator families (17 of 22 families, 77.3%) across all stations affirms good ecological integrity throughout the watershed. Station 1 was dominated by moderately clean water indicators (91.8%), particularly *Filopaludina sumatrensis* (137 individuals). Stations 2 and 3 showed the highest proportions of very clean water indicators. Station 5 exhibited the most complex community, including both sensitive taxa (8 individuals of *Paegniodes sapanensis*) and the study's only dirty-water indicators (3 *Chironomidae* larvae). Temporal patterns showed increasing bioindicator diversity from January to March, consistent with dry-season community consolidation reported by Rahman et al. [14]. It should be noted that dry-season macroinvertebrate assemblages in tropical streams may differ substantially from wet-season communities, particularly for sensitive Ephemeroptera and Plecoptera taxa; the current findings therefore reflect only dry-season baseline conditions.

3.4 Water Quality Classification

All physical parameters (temperature, TDS, pH) met Class 1 standards. Hardness values (12.27–19.18 mg/L mean) were well below the 300 mg/L Class 1 limit. DO was the critical determinant: Stations 2, 3, and 4 (mean DO 4.75, 4.46, 4.65 mg/L) qualified as Class 2; Stations 1 and 5 (4.04 and 3.90 mg/L) were Class 2/3 borderline. A formal table comparing all measured parameters with national standard thresholds, replacing the Table 1 reference in the original manuscript. A modified Water Quality Index (WQI) was computed as: $WQI = 0.3(\text{Physical Score}) + 0.3(\text{Chemical Score}) + 0.4(\text{Biological Score})$. Each sub-score was calculated on a 0–100 scale: Physical Score: each parameter (temperature, TDS, pH) was normalized as (observed value ÷ Class 2 standard value) × 100, capped at 100, then averaged. Chemical Score: hardness and DO values were normalized similarly against Class 2 thresholds. Biological Score: calculated as (proportion of clean and very clean water indicator families at a station) × 100. Station 2 (Waterfall): WQI = 86.7; Station 3 (Dam Head): 86.7; Station 4 (Dam Tail): 76.7; Station 1 (Upstream): 73.3; Station 5 (Canal): 68.3. According to the threshold classification of Pimpunchat [3], Stations 2 and 3 represent excellent water quality (80–100) and Stations 1, 4, and 5 represent good quality (60–80).



Figures 6. Temporal Trends In Hardness and Dissolved Oxygen at Each Sampling Point Over The Three Months

3.5 Management Implications

Stations 2 and 3 (Class 1/2) are suitable for domestic use after minimal treatment. Stations 1 and 4 (Class 2) require conventional treatment before consumption. Station 5 (Class 3) is most suitable for agricultural and industrial uses; conventional treatment, including coagulation/flocculation, multi-stage filtration, aeration, and disinfection, would be required for drinking purposes. For Class 1/2 waters (Stations 2 and 3): basic sand or ceramic filtration followed by disinfection (solar disinfection, chlorination, or boiling). For Class 2 waters (Stations 1 and 4): sedimentation, mixed-media filtration (sand and activated carbon), and disinfection. For Class 3 water (Station 5): coagulation/flocculation using natural coagulants, sedimentation, multi-stage filtration, aeration, and robust disinfection (see Table 2 and Fig. 7). A zoned conservation management approach is recommended: Zone A (Headwaters Protection, Station 1), moderate interventions to manage fine sediment accumulation and place strategic rock deflectors to enhance dissolved oxygen levels without disturbing leaf litter, which provides critical habitat and food resources for macroinvertebrate communities; Zone B (Biodiversity Conservation, Stations 2 and 3) — highest protection, limited access for research and education, continuous monitoring of sensitive taxa (e.g., *Acroneuria abnormis*); Zone C (Sustainable Use, Station 4), designated water collection points, regular DO monitoring; Zone D (Buffer Management, Station 5 and forest boundary), collaborative riparian buffer establishment with adjacent agricultural landowners; Zone E (Riparian Transition Buffer), encompassing the northern forest edge adjacent to agricultural areas, focusing on maintaining riparian vegetation continuity to intercept agricultural runoff before it enters the canal system. Community engagement, environmental education, and careful ecotourism development at Zone B are complementary long-term strategies.

Table 1. Comparison of Measured Water Quality Parameters with Thailand Surface Water Quality Standards (Pollution Control Department, 2022) at Five Monitoring Stations in Ban Pru Toei Community.

Parameter	Station 1 (Upstream)	Station 2 (Waterfall)	Station 3 (Dam Head)	Station 4 (Dam Tail)	Station 5 (Canal)	Class 1	Class 2	Class 3	Water Quality Classification
Temperature (°C)	25.67 ± 1.15	26.00 ± 0.00	26.00 ± 0.00	27.33 ± 0.58	26.00 ± 0.00	≤30	≤30	≤30	All stations: Class 1
TDS (mg/L)	13.69 ± 4.08	11.44 ± 2.60	11.14 ± 3.92	9.68 ± 1.86	12.05 ± 2.44	≤500	≤500	≤500	All stations: Class 1
pH	6.80 ± 0.25	6.72 ± 0.25	6.88 ± 0.20	6.80 ± 0.26	6.65 ± 0.45	5.0–9.0	5.0–9.0	5.0–9.0	All stations: Class 1
Hardness (mg/L)	19.18 ± 3.42	12.65 ± 3.26	12.27 ± 3.73	12.65 ± 1.30	16.52 ± 7.41	≤300	≤300	≤300	All stations: Class 1
DO (mg/L)	4.04 ± 0.33	4.75 ± 1.32	4.46 ± 0.92	4.65 ± 0.84	3.90 ± 0.62	≥6.0	≥4.0	≥2.0	St1: Class 2 St2: Class 2 St3: Class 2 St4: Class 2 St5: Class 3
logical assessment (macroinvertebrates)	Moderately clean water indicators dominant	Clean water indicators dominant (62.5%); Macrobrachium lanchesteri most abundant;	Very clean (20%) + clean (53.3%) indicators; Acroeuria abnormis; Paegniodes sapanensis present; 9 families	Clean (38.5%) + moderately clean (57.7%); 1 Acroeuria abnormis; 8 families	Most diverse (15 families); very clean + clean + moderately clean +	Based on <i>Kanjanava nit</i> (2002) 5- tier system	Based on <i>Kanjanava nit</i> (2002) 5- tier system	Based on <i>Kanjanavanit</i> (2002) 5-tier system	St1, St4: Class 2 St2, St3: Class 1/2 St5: Class 3 (mixed inc. dirty-water Chironomidae)
	Filopaludina sumatrensis (137 ind.); 7 families.								

Table 1. Comparison of Measured Water Quality Parameters with Thailand Surface Water Quality Standards (Pollution Control Department, 2022) at Five Monitoring Stations in Ban Pru Toei Community. (continue)

Parameter	Station 1 (Upstream)	Station 2 (Waterfall)	Station 3 (Dam Head)	Station 4 (Dam Tail)	Station 5 (Canal)	Class 1	Class 2	Class 3	Water Quality Classification
WQI Score (0–100 scale)	73.3	86.7	86.7	76.7	68.3	≥80: Excellent	60–79: Good	40–59: Fair	St2, St3: Excellent (86.7) St4: Good (76.7) St1: Good (73.3) St5: Good (68.3)
Overall Water Quality Class	Class 2	Class 1/2	Class 1/2	Class 2	Class 3	Integrated physicochemical and biological assessment			

Notes: Values are mean ± SD of three monthly measurements (January–March 2023, dry season). Green = complies with Class 1 standard; Yellow = complies with Class 2 but not Class 1 (borderline); Red = does not meet Class 2 standard. Dissolved oxygen was the critical determinant of water class: the Class 1 threshold requires DO ≥ 6.0 mg/L, Class 2 requires DO ≥ 4.0 mg/L, and Class 3 requires DO ≥ 2.0 mg/L [9]. Biological assessment follows the 5-tier pollution tolerance classification of Kanjanavanit [10]. WQI = 0.3×(Physical Score) + 0.3×(Chemical Score) + 0.4×(Biological Score); thresholds from Pimpunchat [3]. Class designations follow the Pollution Control Department Surface Water Quality Standards [9]. All findings represent dry-season baseline conditions; wet-season data are required for annual characterization. See Supplementary Table S3 for monthly parameter values and full WQI component score derivation.

Table 2. Water Quality Suitability and Management Recommendations for Ban Pru Toei Community Forest

Sampling Point	Water Quality Class	Suitable Uses	Recommended Treatment	Conservation Priority
Point 1 (Upstream)	Class 2	Domestic (with treatment), Agriculture, Recreation	Basic filtration, disinfection	Medium
Point 2 (Waterfall)	Class 1/2	Domestic, Agriculture, Recreation, Ecosystem support	Minimal treatment, Basic disinfection	High
Point 3 (Dam Head)	Class 1/2	Domestic, Agriculture, Recreation, Ecosystem support	Minimal treatment, Basic disinfection	High
Point 4 (Dam Tail)	Class 2	Domestic (with treatment), Agriculture, Recreation	Filtration, Disinfection	Medium
Point 5 (Canal)	Class 3	Agriculture, Industrial, Limited recreational use	Conventional treatment	Low

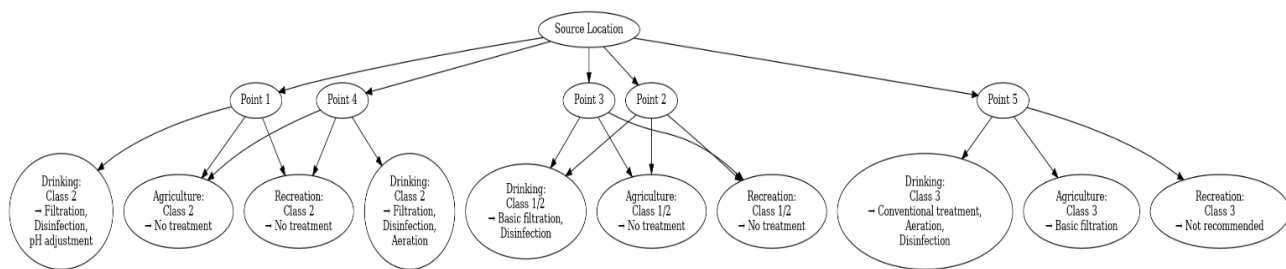


Figure 7. Recommended Water Treatment Processes Based On Source Location And Intended Use

4. Conclusions

This study quantitatively characterized surface water quality during the dry season (January–March 2023) at five stations within the Ban Pru Toei Community Forest (42.56 ha). All physical parameters met Thailand's Class 1 standards (temperature: $26.13 \pm 0.96^\circ\text{C}$; TDS: 11.60 ± 0.13 mg/L; pH: 6.77 ± 0.13). DO was the critical determinant of water class; the overall mean of 4.36 ± 0.10 mg/L placed most stations below the Class 1 threshold of 6.0 mg/L. Biological assessment identified 22 families across 10 orders, with pollution-sensitive taxa (*Perlidae*, *Heptageniidae*, *Ephemeraeidae*) confirmed at Stations 2–5 but absent from Station 1. The WQI ranked Stations 2 and 3 as excellent (86.7) and Station 5 as good (68.3). Stations 1 and 4 are classified as Class 2; Stations 2 and 3 as Class 1/2; and Station 5 as Class 3. All findings represent dry-season baseline conditions; year-round monitoring incorporating the wet season (June–September) is strongly recommended to provide a complete annual characterization of water quality and to evaluate the seasonal stability of macroinvertebrate assemblages. These quantitative baselines support zone-specific conservation strategies and provide essential reference data for long-term monitoring of this community-managed watershed.

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