

MONITORING AND ASSESSMENT OF SURFACE WATER QUALITY IN THE THA THONG RIVER INFLUENCED BY DOLOMITE MINING ACTIVITIES, SURATTHANI PROVINCE, THAILAND

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Abstract

Maintaining surface water quality within regulatory standards is important local communities and ecosystems. The present study aims to monitor and assess the surface water quality in the Thathong River, Surat Thani Province, specifically within the dolomite mining zone throughout the rainy season (May - July 2025). Water samples were taken from 9 monitoring stations to determine physicochemical parameters and amounts of heavy metal. Water temperatures varied from 30.3 to 33.1 °C, electrical conductivity (EC) from 345 to 406 µS/cm, total dissolved solids (TDS) from 173 to 202 mg/L, and total suspended solids (SS) from 1.01 to 34.01 mg/L, with a TDS/EC ratio of 0.50. The value of pH ranged from 7.9 to 8.6, dissolved oxygen (DO) from 9 to 12 mg/L, and biochemical oxygen demand (BOD) from 0.02 to 2 mg/L. The average mean of nitrate-nitrogen and orthophosphate was 2.14 ± 0.84 mg/L and 0.20 ± 0.01 mg/L, respectively. Low quantities of copper, iron, manganese, and lead were discovered, while cadmium and arsenic were not detectable. All detected heavy metals were below the Thailand's class 3 surface water quality standard. The findings provide baseline information to support long-term monitoring and water resource management in mining - influenced catchments.

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According to spatial analysis, land-use activities and soil erosion within mining sites was associated with nutrient accumulation and water - quality deterioration. These results provide essential baseline information for managing water resources and for planning policies and regulations to support long-term environmental monitoring and preservation.

Keywords: heavy metals, Water Quality Index (WQI), mining activities, surface water monitoring, Suratthani

Introduction

The dolomite mining industry is a key export sector that generates significant revenue for Thailand. Several private companies have been granted mining concessions for dolomite [$\text{CaMg}(\text{CO}_3)_2$], comprised of carbonate of calcium and magnesium. Mining areas adjacent to the Tha Thong River extend across the Kanchanadit and Don Sak Districts near Ban Don Bay in Surat Thani Province. The silica content of some dolomite mines of Suratthani province is approximately 0.35% SiO_2 (United Nations, 2016). The region is characterized by a semi-urban-rural interface with a continuing growth of settlements and commercial activities. The mining industry in the area utilizes local natural resources to maximize economic benefit while creating employment opportunities for nearby populations. Mining operations have adopted standardized practices and guidelines consistent with scientific principles for pollution control that are aligned with scientific concepts. Agricultural communities continue to express concerns regarding potential future impacts. In this area, agriculture plays a central role, with water a critical factor in sustaining both human and ecological systems. The residents of the surrounding communities rely extensively on the Tha Thong River for residential, domestic, and agricultural use, and such dependence has led to significant changes in land-use patterns and livelihood practices.

The open-pit nature of dolomite mining and ore-related activities, such as land clearance, ore stockpiling, and ore washing processes, may enhance the hazard of sediment runoff and mineral leaching into the river system, particularly during the monsoon season (Suwanruang, 2019). Water bodies influenced by mining operation may have significant levels of suspended particles and turbidity. Elevated concentrations of iron and aluminum in water may result from erosion processes and the mobilization of

metal – bearing particles. Turbulent flow can also maintain colloid – sized particles or flocculated oxyhydroxides in suspension. Turbidity in specific areas of the water can occasionally indicate metal attenuation processes (Schmiermund & Drozd, 1997). The mining and processing of limestone in the Jaintia Hills, Meghalaya, India, has degraded local water bodies due to elevated maximum concentrations of pH, EC, TDS, hardness, alkalinity, calcium, and sulfate in the effluent during post-monsoon, which were 8.2 ± 0.05 , $27.33 \pm 2.3 \mu\text{S/cm}$, $433.33 \pm 15.27 \text{ mg/L}$, $360.66 \pm 13.61 \text{ mg/L}$, $113.66 \pm 2.08 \text{ mg/L}$, $112.98 \pm 1.75 \text{ mg/L}$, and $654.16 \pm 1.8 \text{ mg/L}$, respectively (Eugene & Singh, 2014). A survey of surface water quality in the Khlong Kram watershed, Tha Uthae Subdistrict, Kanchanadit District, Suratthani Province, located around dolomite mines, revealed that during the wet season, pH, dissolved oxygen (DO), total dissolved solids (TDS), and total suspended solids (SS) ranged from 7.14 to 8.29, 7.2 to 8.57 mg/L, 71 to 363 mg/L, and 6.3 to 11.9 mg/L, respectively. In the rainy season, the electrical conductivity (EC) ranged from 90.5 to 384 $\mu\text{S/cm}$, whereas in the dry season, the value ranged from 149.4 to 341 $\mu\text{S/cm}$ (Duangawat et al., 2016).

Mining - related activities may cause short- and long-term impacts on human health through heavy metal contamination of aquatic ecosystems. Heavy metals can bioaccumulate in organisms and infiltrate the food chain; for instance, high copper above 2.0 mg/L can cause induce nausea, vomiting, and long-term hepatotoxicity (World Health Organization, 2011). Zinc (Zn), although essential at moderate levels, may result in weakness and nausea at levels greater than 3.0 mg/L (Institute of Medicine, 2001). Cadmium ore, a byproduct of lead smelting even at 0.003 mg/L, can accumulate in the kidneys over the long term and cause Itai – Itai sickness characterized by brittle bones and chronic renal failure (Jarup, 2003). Arsenic (As) is also a highly toxic metalloid, with the safe threshold for drinking water set at below 0.01 mg/L. Long-term arsenic exposure has been associated with skin lesions, gastric cancer, and dermatological abnormalities (Smith et al., 2002). Heavy metals in the environment originate from both natural and anthropogenic sources, including rock weathering, industrial discharge, and municipal wastewater (Alkarkhi et al., 2008; Suwanruang, 2019).

The research gap is the lack of monitoring and assessing of the physicochemical characteristics of surface water in the Tha Thong River at upstream, midstream, and

downstream locations in the vicinity of dolomite mining across nine sampling stations. Furthermore, the Water Quality Index (WQI), which has not been previously reported. The findings will provide a scientific basis for future sustainable water resource management and conservation planning to mitigate health risks.

Materials and Methods

Study Area and Sampling Sites

Surface water samples were collected from the Tha Thong River, located between Tha Uthae Subdistrict, Kanchanadit District, and Chai Khram Subdistrict, Don Sak District, Suratthani Province, Thailand, during the rainy season from May to July 2025. The study area extended from 9.16004° N, 99.64832° E to 9.16060° N, 99.64338° E. A total of nine sampling stations were established along the Tha Thong River, covering the upstream (Stations 1 to 3; representing the control area), midstream (stations 4 to 6; adjacent to mining – related discharge and nearby community agricultural activities), and downstream (near stations 7 to 9; receiving cumulative impacts near the irrigation reservoir and government facilities). Each sampling site was spaced at least 500 meters apart and collected at a depth of approximately 0.15 meters below the water surface (Figure 1).

Surface water sampling followed the Standard Methods for the Examination of Water and Wastewater (APHA, 2017). A vertical-type water sampler was used. Collected samples were transferred into pre-cleaned and sterilized polyethylene containers to prevent contamination from surface residues. After collection, all samples were preserved in a cool box (4°C) and transported to the laboratory within 24 hours for subsequent analysis.

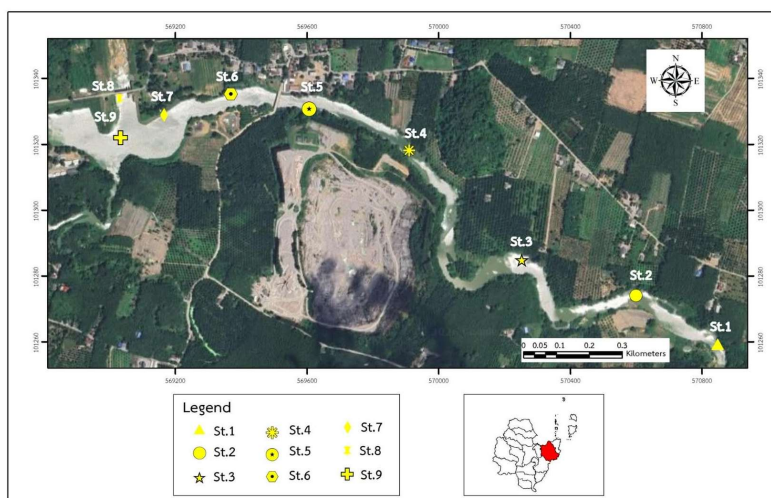


Figure 1 Water sample collection sites along the Tha Thong River around the dolomite mines of Suratthani province.

Water Quality Analysis

Physical parameters, including temperature and EC, were measured in the field using a portable multiparameter meter. TDS and SS were analyzed in the laboratory using glass fiber filters pre-dried at 103 – 105 °C. Chemical parameters were analyzed as follows: pH was measured by pH meter; DO and BOD were determined using the Azide Modification method; nitrate-nitrogen (NO_3^- -N) was measured by the Cadmium Reduction method; and orthophosphate (PO_4^{3-}) was analyzed using the Ascorbic Acid method. Secondary elements: potassium (K), calcium (Ca), and sodium (Na) were quantified using a flame photometer. For heavy metal determination, water samples were filtered using 0.45 μm membrane filters and digested with concentrated nitric acid (HNO_3) prior to analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS; Perkin Elmer). The examination of heavy metals were As, Cd, Cu, Fe, Mn, and Pb using the Standard Methods for the Examination of Water and Wastewater (APHA, 2017). QA/QC for ICP-MS, instrument calibration of five concentration points of standard solutions to calibrate instruments before application. The correlation coefficient (R^2) of the multi-element standard was greater than 0.995. The limit of detection (LOD) for As, Cd, Cu, Fe, Mn, and Pb of atomic spectroscopy was 0.0003, 0.00006, 0.00003, 0.0001, 0.00005, and 0.00001 $\mu\text{g/L}$, respectively. The background of blank ($n = 10$) was less than LOD. The relative standard

deviation of the triplicate sample was less than 10%. The recovery percentage was checked in the range of 90 to 110%.

Water Quality Assessment

Surface water quality was assessed using the Water Quality Index (WQI), based on the modified equation proposed by Sudcha (2008) and the criteria of the Royal Irrigation Department (RID, 2018). The results were interpreted according to the surface water quality standards of the Pollution Control Department (PCD, 1994).

Data Analysis

The results among all surface water quality stations were compared against the Thai Surface Water Quality Standards (Pollution Control Department, 1994; Royal Irrigation Department, 2017). Water quality parameters across three surface water groups were analyzed using descriptive statistics, including means and standard deviations (SDs). One-way analysis of variance (ANOVA) with multiple comparisons (Tukey-Kramer) was deployed. A box plot was used to visualize the distribution of water quality parameters among groups. Statistical significance was assured using one – way ANOVA followed by Tukey – Kramer post hoc tests at a 95% confidence level.

Results

The study of surface water quality at nine sampling sites in areas adjacent to mining activities in Suratthani Province revealed that the physicochemical properties of surface water generally complied with the Class 3 surface water quality standards of the Pollution Control Department (PCD, 1994). In terms of physical characteristics, water temperature ranged from 30.3 to 33.1 °C, and electrical conductivity (EC) ranged from 341 to 406 $\mu\text{S}/\text{cm}$.

Total dissolved solids (TDS) ranged from 173 to 202 mg/L, with an average TDS-to-EC ratio of 0.50. This ratio represents the normal relationship between solute concentration and electrical conductivity of brackish water affected by saline intrusion from Bandon Bay, Suratthani Province. The TDS/EC ratio among all stations was 0.50. Turbidity, represented by SS, ranged between 1 and 34 mg/L. The chemical analysis indicated that pH, dissolved oxygen (DO), and biochemical oxygen demand (BOD) ranged from 8.2 to 8.7, 9 to 12 mg/L, and 0.5 to 2 mg/L, respectively. The greater primary nutrient concentrations were found in the nitrate (0.97 to 3.12 mg/L) and orthophosphate (0.18

to 0.23 mg/L), were higher at stations 6 and 7, which were relatively higher than the other stations. The average concentrations of nitrate–nitrogen and orthophosphate across all samples were 2.14 ± 0.84 and 0.20 ± 0.01 mg/L, respectively. The average values of the secondary elements K, Ca, and Na in surface water across for all stations were 0.16 ± 0.1 , 9.88 ± 6.44 , and 3.38 ± 4.16 mg/L, respectively.

According to the Royal Irrigation Department (RID, 2018). The mean Water Quality Index (WQI) score was 53 (range: 46–58), indicating moderately deteriorated water quality standards equivalent to Class 3. These results suggest a moderate decline in water quality, despite compliance with national standards for some parameters (Table 1).

Table 1 Physicochemical characteristics of water quality along Tha Thong River around dolomite mines, Suratthani province.

Station	Temp (°C)	pH	EC ($\mu\text{S}/\text{cm}$)	TDS (mg/L)	SS (mg/L)	DO (mg/L)	BOD (mg/L)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	K (mg/L)	Ca (mg/L)	Na (mg/L)
St.1	30.31	8.60	406	202	4.01	9.50	2.00	0.97	0.19	0.009	0.97	0.97
St.2	31.41	8.50	396	199	1.01	11.00	1.50	1.97	0.20	0.005	0.97	0.65
St.3	32.20	8.20	376	200	12.01	9.00	1.50	1.51	0.21	0.235	11.07	1.62
St.4	31.90	8.10	345	198	19.01	10.00	0.50	1.23	0.19	0.211	9.12	1.30
St.5	32.00	8.60	367	183	28.01	9.00	0.50	2.96	0.18	0.137	8.79	4.88
St.6	31.40	8.50	381	192	2.01	9.50	0.50	3.12	0.19	0.116	9.77	1.31
St.7	31.31	8.60	378	189	19.01	12.00	1.00	2.99	0.19	0.288	14.33	5.86
St.8	33.10	7.90	341	201	3.01	10.50	1.00	1.69	0.23	0.279	23.12	13.68
St.9	32.50	8.30	351	173	34.01	10.00	0.02	2.87	0.19	0.105	11.72	ND
Min–	30.31–	7.90–	341–	173–	1.01–	9.00–	0.02–	0.97–	0.18–	0.005	0.98–	0.00–
Max	33.10	8.60	406	202	34.01	12.00	2.00	3.12	0.23	–0.30	23.12	13.68
Mean $\pm$	31.79 $\pm$	8.37 $\pm$	371.22	193.00	13.57	10.17 $\pm$	0.95 $\pm$	2.14 $\pm$	0.20 $\pm$	0.16 $\pm$	9.88 $\pm$	3.38 $\pm$
SD	0.80	0.25	± 22.40	± 9.82	± 12.16	0.98	0.63	0.84	0.01	0.10	6.44	4.16
F test	ns	ns	*	*	*	*	*	*	*	ns	*	*
CV (%)	2.52	3.04	6.03	5.08	89	9.77	66	200	6.96	65	65	123
PCD	≤ 3 °C	5.0–	–	–	–	≥ 6	≤ 1.5	–	≤ 5	0.01	0.1	1.0
Standar d ¹	(from natural)	9.0										
RID	≤ 40	6.5–	$\leq$	$\leq$	–	≥ 2	≤ 20	–	–	–	–	–
Standar d ²		8.5	2,000	1,300								

Sources PCD Standard¹ and RID Standard²

Remark ND = Not Detected, ns = Not significantly different at the 95% confidence level

“–” = Parameter not measured

Copper, iron, manganese, and lead were detected at low concentrations, whereas arsenic and cadmium were not detected. All detected heavy metals were below the Class 3 surface water quality standards.

The box plot demonstrated all physical and chemical parameters of surface water were classified into three groups of sampling sites (upstream, middle stream, and downstream) around the mining zone of Suratthani province and found that SS, TDS, EC, temperature, BOD, DO, NO_3^- , PO_4^{3-} , Fe and temperature were significant with a p -value of 0.05 (Figures 2-4).

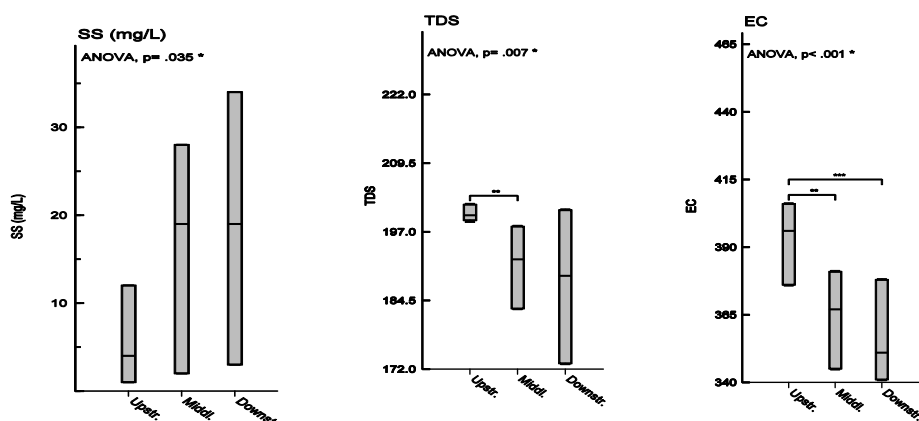


Figure 2 Physical properties (SS, TDS, EC) of surface water among upstream, middle stream, and downstream around dolomite mines of Suratthani province.

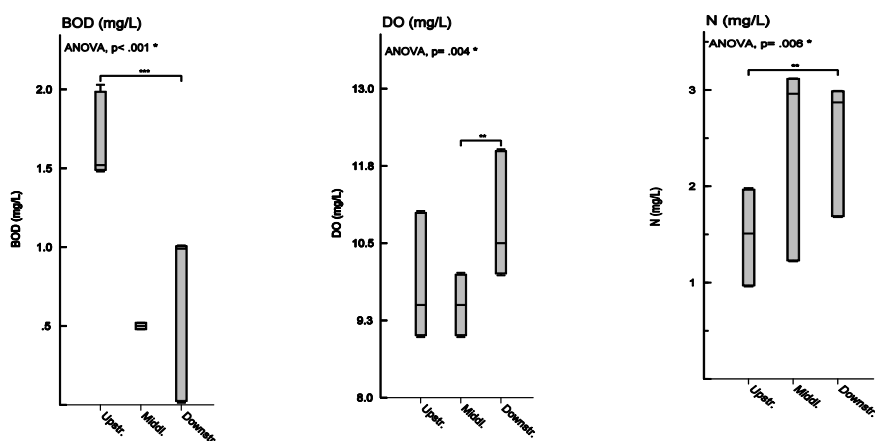


Figure 3 Chemical properties (BOD, DO, NO_3^-) of surface water among upstream, middle stream, and downstream around dolomite mines of Suratthani province.

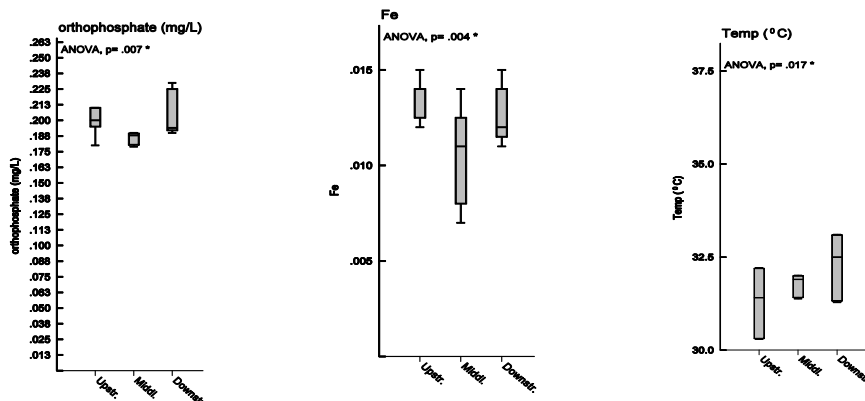


Figure 4 Physical and chemical properties (phosphate, Fe, temperature) of surface water among upstream, middle stream, and downstream around dolomite mines of Suratthani province.

PCA analysis to identify key influencing factors revealed that the first two principal components accounted for 72% of the total variance. The separation between the three groups of upstream (st.1 to 3), middle stream (st.4 to 6), and downstream (st. 7 to 9) was rather apparent. Although one of the downstream sites was found to the right of one of the upstream groups. Generally, the upstream sites exhibit higher pH, EC, TDS, and BOD (Figure 5).

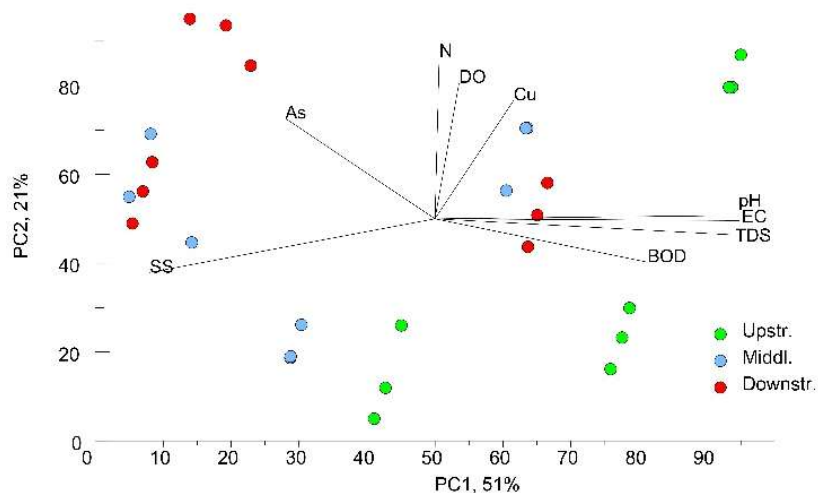


Figure 5 Principal Component Analysis (PCA) of surface water among upstream, middle stream, and downstream around dolomite mines of Suratthani province.

Discussions

The average TDS-to-EC ratio for surface water was consistent with the study by Al-Kubaish et al. (2024), which reported an average of 0.55, and Thirumala et al. (2014), who reported an average of 0.64. The study results of low levels of SS except for st.4, 5, 7 and 9, indicating relatively low sediment loads, are suitable for aquatic life and water utilization, which are lower than the findings of Duangsawat et al. (2016) who reported SS concentrations ranging from 6.3 to 11.9 mg/L in the main streams and tributaries of the Khlong Kram watershed, Tha Uthae Subdistrict, Kanchanadit District, Suratthani Province, during the wet season. Water and sediment samples were collected from nine sampling stations during the wet season (December 2014) and the dry season (April 2015), revealing BOD values up to 2.3 mg/L, which were slightly higher than the present study's degraded surface water quality BOD value of 0.95 ± 0.63 mg/L. Furthermore, heavy metals, particularly high arsenic (As) concentrations in surface water at station SW2 (0.0201 mg/L during the dry season), exceeded surface water quality standards, whereas the present study showed a low level of As below surface water quality standards (0.001 ± 0.00 mg/L). The pollutant trends in this area improved quality for BOD and As were taken into account. The range of EC of the present study (341 and 406 $\mu\text{S}/\text{cm}$) was slightly lower than the levels of agricultural and domestic pollution compared to other rivers in the region, where EC levels commonly exceeded up to 600 $\mu\text{S}/\text{cm}$ of EC due to agricultural runoff and soil leaching (Islam & Mostafa, 2015). The value of turbidity, represented by SS, ranged between 10 and 16 mg/L, which was not particularly high; however, during the rainy season, this value may increase due to soil erosion (Pawar & Pande, 2020). The ideal TDS-to-EC ratio is roughly 0.64, along with other parameters, has been demonstrated to enhance the accuracy of surface water quality assessment (Thirumala et al., 2014).

Chemical characteristics of surface water: pH values ranged from 8.1 to 8.6, with stations 1, 5, and 7 exhibiting the highest values (up to 8.6), probably as a result of the dissociation of bicarbonate ions separating from dolomite. These alkaline pH values are closely aligned with those reported by Xu et al. (2022), who investigated karst regions in Southwest China, particularly the Chishui River Basin. The main cause of elevated total alkalinity and dissolved inorganic carbon in river systems is carbonate weathering. The mining

process accelerates the chemical breakdown of dolomite [$\text{CaMg}(\text{CO}_3)_2$], thereby releasing significant amounts of bicarbonate ions into the water column. Alkalinity from rock weathering, which was helped by dolomite crushing, was the main regulator of water chemistry. These bodies of water of the Jaintia Hills, Meghalaya, India, have increased in dissolved cationic water pollutants, which could be caused by limestone breakdown (Eugene & Singh, 2014).

High DO concentrations with a mean value of 10.00 ± 0.93 mg/L, are sufficient to sustain aquatic life and demonstrated BOD values with a mean value of 1.11 ± 0.54 mg/L, indicating low levels of biodegradable organic matter (Duangsawat et al., 2016). The relationship between DO and BOD is a critical indicator of water quality and aquatic environmental conditions. For instance, in 2016, DO and BOD values in the Madiun River in Indonesia were observed range from 3.1 to 8.0 mg/L, and 4.9 to 13.7 mg/L, respectively, whereas in 2017, DO concentrations varied from 4.7 to 8.36 mg/L, while BOD ranged from 3.7 to 9.52 mg/L. These variations were influenced by several factors, including population density, agricultural area, livestock numbers, domestic wastewater discharge, and rainfall. Such factors increase the organic load in water, thereby increasing microbial oxygen demand for the decomposition of organic and inorganic substances, thereby decreasing oxygen concentrations in aquatic environments (Susilowati, 2018). Certain metals, such as Fe and Zn, are essential micronutrients for microbial growth; these microbes naturally decompose organic matter in aquatic ecosystems, thereby reducing water deterioration. However, all heavy metals in this study were within the standard limitations. Excessive concentrations of trace elements can create toxic environments (Chotchayanpong et al., 2019). The high levels of Cd (0.026 mg/L) from off-Pattani Bay and Pb (0.184 mg/L) from in-Pattani Bay, Thailand, during the wet season were contaminated in Pattani Bay, Thailand, which was higher than that of the study area (Imsilp et al., 2025). In contrast, the present study detected no cadmium in any station, highlighting a more favorable status of heavy metal contamination in the study area.

Numerous international studies on heavy metal contamination in water resources revealed differences in pollution levels, which were impacted by both human activities and environmental factors. Khan et al. (2023) reported mean concentrations of Cr (0.04 mg/L), Ni (0.04 mg/L), Cd (0.04 mg/L), Pb (0.03 mg/L), As (0.001 mg/L), and Fe

(0.04 mg/L) in surface waters close to industrialized areas in Pakistan's Eastern Hindukush region, which were considerably higher than those found in the present study, suggesting lower anthropogenic pressure in the study region. Fe and Pb concentrations in the Yamuna River, India, ranging from 0.25 to 0.87 mg/L, respectively, with high values during the dry season (Jaiswal et al., 2022). Whereas, the study area exhibited minimal seasonal variation, suggesting more stable hydrological and ecological conditions. Prasad et al. (2020) reported Fe (1.02 mg/L), Mn (0.68 mg/L), Zn (0.47 mg/L), Cr (0.21 mg/L), and Pb (0.19 mg/L) concentrations in the Upper Ganga River of India which were found to be exceeded the national standards, while the level of heavy metals in the present study area showed close to or below allowable limits, signifying lower pollution severity. The study by Noormohammadi et al. (2025) measured presence of As (0.013 mg/L), Cd (0.007 mg/L), and Hg (0.004 mg/L) in Northwestern Iran, indicating health concerns in some areas; lower corresponding values in the study area indicated safer water quality. Majumdar et al. (2024) found high values of Heavy Metal Pollution Index (HPI) values ranging from 48 to 112 with seasonal spikes during the monsoon, whereas your indices were comparatively lower indicating stable water quality. The study of Li et al. (2023) found that the levels of Pb (0.09 mg/L) and Cd (0.05 mg/L) in agricultural irrigation canals in Eastern China were above irrigation standards because of fertilizer runoff. Compared with these findings, Pb and Cd concentrations in the present study were lower than these finding, implying better land management and minimal agrochemical contamination. Compared with previous studies, this result indicates relatively low levels of heavy metal contamination in most cases. This trend could be attributed to the geographic characteristics of the study area—its distance from industrial and agricultural hotspots and its maintenance of a more balanced aquatic ecosystem. Water quality around the middle stream close to the mining area was relatively higher than upstream and downstream, which was significant among all water variables.

In the present study, the evaluation of the Water Quality Index (WQI) by Sudcha (2008) yielded values ranging from 48 to 54 (with a mean of 51), as well as, the WQI calculated according to the Royal Irrigation Department (2018), corresponded with a mean score of 53 (range from 46 to 58), indicating a good water quality level by Nigerian standard, which are employed in the criteria level between 50 and 100 (Yisa & Jimoh,

2010). The water quality standard in Thailand is met, classified as class 3, indicating a moderate level. In accordance with the Huai Luang River, which serves as the municipality's primary water source in Udon Thani Province, Thailand, the WQI was found in the range of 54 – 60 scores. Water pollution is primarily caused by human activities, agriculture, and animal farming (Phitaktim et al., 2023).

Conclusions

The monitoring and assessment of surface water quality in the Tha Thong River around mining in Suratthani Province, covering both physical and chemical parameters at the nine sampling stations, were below the standard levels for Thai surface water, except for the alkaline pH at stations 1, 5, and 7, which may be attributed to dolomite mining, which affects aquatic habitat suitability. Some stations were impacted, with elevated Ca and Na concentrations at station 8 and higher suspended solids at station 7, indicating potential localized areas of concern for ongoing security monitoring. Although all heavy metals were below the standard limits, these results indicate a moderate decrease in water quality concerns. Regarding the WQI of the Thai standard, which complied with Class 3 (moderate water quality), whereas the WQI based on the Nigerian standard indicated good quality. As a result, the overall water quality in this study area seems to be safer and less affected by environmental pollution than in previous studies. The obtained data can be used as a baseline for integrated water management planning, environmental protection, and restoration measures. To support future research, the integration of information on land use, mining activities, and water resources is recommended to guide policymakers in developing strategies and regulations that promote environmental and social sustainability. In addition, the health risk assessment and ecological risk index of surface water would be studied.

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