Assessment of Surface Water Quality of Huai Luang River in Udon Thani, Thailand, Using the Water Quality Index

S. Phitaktim, C. Wangka-orm, S. Wesetsri, T. Togari, S. Sato, and M. Wongaree*

***Abstract*—This study aimed to analyze the surface water quality of the Huai Luang River using the water quality index (WQI) method. Five parameters were analyzed to assess the water quality of the Huai Luang River; they were dissolved oxygen (DO), biochemical oxygen demand (BOD), total coliform bacteria (TCB), fecal coliform bacteria (FCB), and ammonia (NH_3). The Huai Luang River is the municipality's primary consumption water source in Udon Thani province, Thailand. WQI classifications were calculated by using the surface water quality standards program of Thailand's Pollution Control Department (PCD-WQI). The results showed that the water quality in the Huai Luang River was bad status, in the WQI range of 54-60 scores. The major sources of pollutants in the Huai Luang River were wastewater from communities, agriculture, and animal farms are the main contributors to water pollution. Seasonal water quality variations were observed at each monitoring site from March 2022 to February 2023. WQI concentration in the rainy season (March to June) was generally among the highest (57 score) compared with other seasons (56 score in winter and 54 score in summer). While the WQI concentration of the upstream sampling site (domestic wastewater) had the lowest (55 score) compared with the other sites (59 score for midstream and 60 score for downstream). Therefore, this research study presented valuable information on WQI for the Huai Luang River for water quality management by administrators and local community participation.**

***Index Terms*—Water quality index, Surface water quality, Huai Luang River, Udon Thani**

I. Introduction

Huai Luang River is one of the northeast of Thailand's most important rivers, which starts in Nong Bua Lamphu province. The river flows past Udon Thani City and into the Mekong River in Nong Khai Province [1]. It plays a vital role in the lives of people along this river. Generally, river water in Thailand is primarily used for agriculture, fisheries, and community consumption [2, 3]. Agriculture, animal farms, and domestic users are the major water consumers of the Huai Luang River. Currently, the water quality status of Huai Luang River is experiencing severe problems. The main source of water pollution was wastewater discharge directly into the river. This wastewater contained toxic substances and was high in organic matter [4, 5]. The surface water contaminants were predominantly from the discharge of municipal, agricultural, animal farms, and oil leaching [6]. Thus, it has become imperative to regularly check the water quality by evaluating physico-chemical and biological parameters. According to previous research, the rivers' water quality monitoring results indicated that the Huai Luang River has been facing water pollutant problems with low quality according to the surface water quality standard [7, 8]. Various management approaches have been applied to tackle the water pollution problems in the Huai Luang River. Such as; establishing receiving water quality standards, classification based on existing benefits, setting up effluent standards for major pollution sources, monitoring receiving water quality and effluent from the point source pollution, and constructing wastewater treatment plants in the municipalities; however, it is currently not very effective.

To assess the water quality, various methods and techniques have been proposed and adopted by researchers worldwide, of which the most effective approach was the use of the water quality index (WQI) [9, 10]. WQIs are considered reliable and extensively used for aquatic environmental monitoring [11]. The WQI method is a mathematical method to assess the surface water quality of varying river types [12, 13]. It has been widely applied to assess surface water and groundwater quality [14, 15]. Several researchers have utilized a range of applications of WQI to evaluate the water quality of rivers, lakes or reservoirs. WQI methods were widely developed and practiced in the ASEAN region that used for river water, surface water, reservoir or lake, including in Thailand. WQI concentrations reflect the water quality conditions by using a numerical score. Making it easier for the public and policymakers to understand the condition of an aquatic environment [16]. It also assesses the suitability of the water quality for an array of uses, such as agriculture, aquaculture, and domestic use [17, 18]. In Thailand, the WQI was developed by Thailand's Pollution Control Department (PCD) and has been used as the standard calculation method by the water quality monitoring program [19]. It is the standard method for examining the most significantly affected surface water sources. Since there have already been numerous studies investigating water quality conditions using WQI in Thailand, but no study has been reported on the WQI values of the river in the local Udon Thani city.

Therefore, the objectives of this study were to analyze the surface water quality of the Huai Luang River in Udon Thani. Surface water quality was also classified for the river status according to the WQI method using the calculating program of surface water quality standards approved by the Pollution Control Department in Thailand (PCD-WQI). To assess the surface water quality of the river, this work analyzed samples from three sampling sites located upstream, midstream, and downstream of the Huai Luang River. The major wastewater

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sources were domestic wastewater, animal farms, and agriculture; all are major contributors to the water pollutant problem. The parameters of dissolved oxygen (DO), biochemical oxygen demand (BOD), total coliform bacteria (TCB), fecal coliform bacteria (FCB), and ammonia (NH_3) were investigated monthly over one year (March 2022–February 2023) by using the standard procedures. In addition, water quality analysis was also observed for the seasonal variation at each monitoring site. As a future direction, an assessment of WQI purpose and the level of treatment required should be defined to ease policymakers in designing of water treatment abatement strategies.

II. METHODOLOGY

A. Study Area

Assessment of surface water quality of the Huai Luang River in Udon Thani, Thailand using the WQI consisted of three sampling sites, as illustrated in **Fig. 1**. At each sampling site, the water was collected and measured to represent the water quality upstream, midstream, and downstream. Each sampling site was positioned by the global positioning system (GPS). Water samples were collected monthly over one year (March 2022-Febuary 2023).

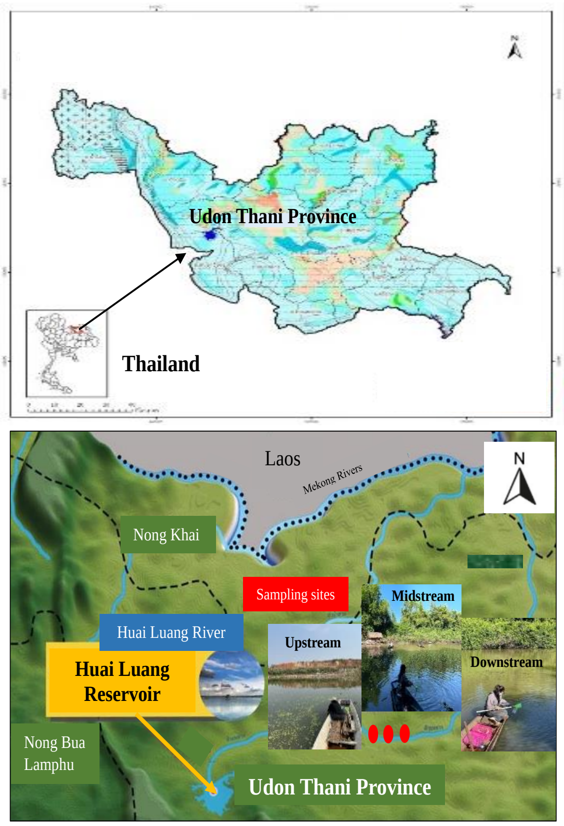

Fig. 1. Study area with various sampling sites.

Five water quality parameters were measured in the environment laboratory. The study area was selected from the Huai Luang River, covering the Sam Phrao and Nong Khon Saen communities in Udon Thani City. The length of the Huai Luang River in this work was approximately 10 km. The river is 2–3 m deep and 3–5 m wide, an important area for local community residents, animal farms, and agriculture. The names and locations of the different sampling sites are described in Table I. The samplings were collected during the three seasons; seasons were categorized as follows; summer (March-June), rainy season (July-October), and winter (November-February).

TABLE I: WATER SAMPLING SITE POSITION

Sampling Site	Wastewater sources	X	Y
Upstream	Domestic wastewater	277737	1931593
Midstream	Animal farms	281846	1933188
Downstream	Agricultures	283176	1932107

B. Water Quality Parameters

The water samples were analyzed by using the WQI method with five parameters based on DO, BOD, FCB, TCB, and NH_3. Water samples from each sampling site were collected manually using polyethylene bottles (1L). The bottles were cleaned with 2% HNO_3 and then rinsed with distilled water before use. DO and BOD were analyzed in a laboratory by using the azide-modification method and the 5-day BOD test 5210B [15]. All of the bacteriological parameters, fecal coliform bacteria (FCB) and total coliform bacteria (TCB), were ascertained according to the standard methods (APHA 2012). Ammonia (NH_3) was measured using the nesslerization method with a spectrophotometer. All physico-chemical parameters were performed according to the standard methods [20].

C. Water Quality Index (WQI) Classifications

The surface water quality of the Huai Luang River was calculated and assessed by using the WQI method developed by the Pollution Control Department, Thailand (PCD-WQI). The program of PCD-WQI calculation was described in detail by the previous research [19]. Ratings of the WQI were classified into five ratings (very good, good, medium, bad and very bad), as illustrated in Table II.

TABLE II: WQI INTERPRETATION

Surface water quality standard of the Pollution Control Department (PCD) in Thailand	**WQI Score**	**WQI Rating**
Type I: Extra clean fresh surface water resources used for the conservation not necessarily pass through water treatment process require the only ordinary process for pathogenic destruction and ecosystem conservation where basic organisms can breed naturally.	91–100	Very good
Type II: good clean surface water resources used for the consumption which requires pre-water treatment process before use and used for the aquatic organism conservation, fisheries, and recreation.	71–90	Good
Type III: Medium clean fresh surface water resources used for consumption, but passing through an ordinary treatment process before using and used for agriculture.	61–70	Medium
Type IV: Fairly clean fresh surface water resources used for the consumption, but require special water treatment process before using, and used for industry.	31–60	Bad
Type V: The sources which are not the classification in Types 1-4 and used for navigation, conditions usually depart from natural or desirable levels.	0–30	Very bad

The obtained data analysis with five parameters was calculated following the website; http://iwis.pcd.go.th/index.php?method=calculate&etc=1681956372255&fbclid=IwAR0cyGAfVgAU7pU-wk-6HsbDvm2x-7ShEqOrjIdbfziUxbyO2bog0-KBtWw. The obtained results of the surface water quality assessment of the Huai Luang River were then classified for the type of surface water utilities that impacted the river as per the surface water quality standard of the Ministry of Natural Resources and Environment in Thailand.

D. Static Analysis

The results of the water quality of the Huai Luang River were analyzed by the mean and standard deviation (SD) and analysis of variance with an independent sample test using SPSS Statistics version 22.0. The significance level of the tests was taken as $p < 0.05$.

III. Results and Discussion

A. Surface Water Quality Analysis

The main source of water pollution of the Huai Luang River in Udon Thani comes from various wastewater activities of communities, agriculture, and animal farms, which occupies roughly 70%, 30%, and 10% of the river's area, respectively. The average temperature of the water between locations from upstream to downstream was not significantly different and ranged from 32.29±2.23 to 32.83±1.49 ℃, as illustrated in Table III. It fluctuated between March 2022 to February 2023 from 30.77±2.22 to 33.63±0.72 ℃ by the significant ($p < 0.05$), as illustrated in Table IV. The upstream to downstream pH ranged between 6.64±0.45 to 7.32±0.45, while the pH over one year ranged between 6.58±0.26 and 7.55±0.41 (Table IV). The pH at all locations was within the allowable limit of surface water quality standards in Thailand (Std. pH 5.0–9.0).

TABLE III: Water Quality Analysis of Huai Luang River

Parameter	Water quality concentration (Average ± SD)		
	Upstream	Midstream	Downstream
Temperature (℃)	32.29±2.23	32.83±1.49	32.60±2.41
pH	7.32±0.45	6.89±0.54	6.64±0.45
DO (mg/L)	4.73±0.42	5.05±0.87	4.84±0.35
BOD (mg/L)	2.32±0.77	1.81±0.89	1.69±0.46
TCB (mg/L)	101,750±11,385	82,050±13,307	79,767±10,791
FCB (mg/L)	14,988±2,792	12,641 ± 2,481	12,210±2,461
NH_3 (mg/L)	0.79±0.15	0.66±0.13	0.56±0.12

Table III shows the concentration of DO upstream was 4.73±0.42 mg/L, while the midstream and downstream had DO concentrations of 5.05±0.87 mg/L and 4.84±0.35 mg/L, respectively. The results showed that the concentration of DO was not significantly different at all sampling sites. However, the average DO concentration was lower than the permissible limit of DO ≥ 6 mg/L, compared with the surface water standards of PCD in Thailand, with Type II: surface water resources used for consumption requiring a pre-water treatment process before use. Then it can be used for aquatic organism conservation, fisheries, and recreation. DO is one of the important parameters in water quality analysis that indicates the amount of oxygen available in the water. DO concentration factors depend on parameters such as temperature, photosynthetic activity, wind action, the respiratory process of the life in it, and the pollution load [10, 15]. If the DO concentration is low, it indicates that the water has been contaminated. Furthermore, it also fluctuates daily, seasonally, and with temperature variations. The concentration of DO also shows the extent to which the surface water can accommodate water organisms such as fish and microorganisms.

For the BOD, this parameter indicated the amount of oxygen microorganisms require to decompose dissolved organic substances and some organic substances suspended in water. The greater the concentration of BOD means the decomposition of organic substance occurs in large quantities and will absorb oxygen in water, thereby reducing the amount of DO. As a result, the BOD concentration decreased from upstream to downstream. The highest BOD concentration occurred in the upstream area (2.32±0.77 mg/L), while the BOD concertation at midstream and downstream was lower (1.81±0.89 mg/L and 1.69±0.46 mg/L). The decrease in BOD concentration from upstream to downstream indicates that the river water quality has increased. However, the average BOD concentration from all samplings was lower than the permissible limit of BOD ≤ 1.5 mg/L compared with the surface standards of PCD. This is because the source of pollutants is not only from the previous water flow but also from the surrounding settlements that dispose of domestic wastewater, agricultural activities, and animal farm waste directly into the river.

TCB concentration from upstream was 101,750±11,385 MPN/100 mL, while midstream and downstream were 82,050±13,307 and 79,767±10,791 MPN/100 mL. The highest TCB concentration occurred upstream, while the downstream had the lowest TCB concentration. The higher TCB concentration at the sampling sites upstream and midstream can be attributed to domestic wastewater disposal and animal farms in the area. The TCB concentration limitation in river water should be under 5,000 MPN/100 mL for domestic water, fishery, and agriculture. However, the results showed over the limit of the surface water standard as it exceeded the TCB standards in Thailand.

FCB concentration upstream was the highest with 14,988±2,792 MPN/100 mL, while midstream and downstream had lower FCB concentrations of 12,641 ± 2,481 MPN/100 mL and 12,210±2,461 mg/L, respectively. A high FCB concentration mostly coursed from wastewater that discharged nearby community areas and farm animal activities. The detection of coliform bacteria in feces resulted from humans and animals. It is an important parameter to indicate as high FCB concentration can lead to disease pathogenesis, and the pathogenesis of the disease affects humans. The results exceeded (≤ 1,000 MPN/100 mL) the limit of the surface water standard.

The concentration of NH_3 showed the upstream concentration was 0.79±0.15 mg/L, while the midstream and downstream had NH_3 concentrations of 0.66±0.13 mg/L and 0.56±0.12 mg/L. The highest NH_3 concentration also occurred in the upstream area, while the downstream of the river had the lowest NH_3 concentration. The NH_3 nitrite-nitrogen concentration accumulated and exceeded the allowable limit of 0.5 mg/L. However, the results showed that all samples exceeded the limit of the surface water standard. BOD, TCB, and FCB are the top three parameters with the highest concentration of occurrence in the upstream reaches during the sampling year, highlighting BOD, TCB, and FCB as important factors which encumber the Huai Luang River water quality. This suggests an association between nutrient pollution and suspended sediment loading across the Huai Luang River, possibly from soil erosion and agricultural runoff. The parameters BOD, TCB, and FCB were positively correlated with the proportion of domestic wastewater, animal farms, and agriculture. In that order, the correlation was significant for TCB, FCB, and BOD. Moreover, in the previous research, the correlation between TCB and the proportion of community activity (domestic sewage or municipal sewage, animal farms' wastewater, and agriculture) had the highest coefficient compared with other factors. For more understanding, high-intensity human activities cause domestic sewage to contain many bacterial pollutants such as BOD, TCB, and FCB, including NH_3.

B. Seasonal Variations

Water samples were collected monthly over one year (March 2022-Febuary 2023) at three sampling sites to compare seasonal variance. The water quality of the Huai Luang River was measured during three seasons; summer (March-June), rainy season (July-October), and winter (November-February) representing the seasonal characteristics of the Huai Luang River. The DO concentration significantly differed ($p < 0.05$) from summer to rainy season. The average DO concentration gradually increased from the summer (4.19±0.34 mg/L) to the rainy season (5.88±0.24 mg/L), while in the winter, it was detected at 4.55±0.36mg/L. The highest DO concentration was observed at the midstream sampling site in winter (6.26±0.39mg/L), while the lowest DO concentration was also detected at the same site at 4.09±0.80 mg/L in the summer.

The average concentration of BOD was the highest in the summer (2.68±0.88 mg/L) compared with the other seasons. The average lowest BOD concentration was observed in the rainy season at 0.89±0.24mg/L, while the average BOD concentration in the winter was 1.67±0.46 mg/L. The maximum occurred upstream in the summer and had a BOD concentration of 2.24±0.23 mg/L. BOD in the rainy season fluctuated more than in the summer and the winter seasons. The annual average BOD concentration at most of the sampling sites (Table III) was more than 1.5 mg/L exceeding the allowable limit of surface water standard of 1.5 mg/L. While the monthly average concentration of BOD_5 varied by seasonal was significantly different ($p < 0.05$). Especially, BOD concentrations with all of sampling sites in the summer and winter (Table IV) are mostly exceeded in the limit BOD standard. The concentration of BOD reflected the degree of pollution from domestic, agricultural, animal farms, and living organic pollutants.

Regarding bacteriological parameters (TCB and FCB), the summer had the worst water quality compared to other seasons. Showing the number of bacteria was higher at the upstream sampling site than those found in the other water sampling sites. The coliform bacteria group can indicate cleanliness and contamination from human and animal waste in water resources, which is usually found in the gastrointestinal tract of humans and animals. The average concentrations of TCB were detected at 110,750±16,371 MPN/100 mL in the summer, 59,025 ±6,623 MPN/100 mL in the rainy season, and 93,792 ±8,957 MPN/100 mL in the winter. The summer and winter season analysis results were higher than the rainy when comparing the seasonal variations with the significantly different ($p < 0.05$). The maximum TCB concentration was measured in the summer at the upstream site (128,750 ±12,914 MPN/100 ml), a high concentration from wastewater discharged from domestic wastewater or municipal activities. The minimum TCB concentration was measured in the rainy season at the downstream site (51,150±7,227 MPN/100 ml), a concentration from wastewater discharged from agriculture activities. However, the average concentration of TCB from the three sampling sites did not show significant trends.

The average concentration of FCB found in the summer, rainy, and winter seasons was 19,538 ±2,642, 8,652± 1,413, and 11,650±1,269MPN/100 mL, respectively. The highest FCB concentration was measured at the summer upstream site (22,500±3,103 MPN/100 mL), while the lowest FCB concentration was measured in the rainy season at the downstream site (7,569±1,408 MPN/100 mL). Obviously, the average concentration of FCB from the three sampling sites did not show significant trends. Comparing the seasonal, the rainy season had lower FCB concentrations than the other seasons, because the rainy affected. FCB is found only in the feces of warm-blooded animals. Therefore, FCB is a good indicator of the risk of contamination from pathogens from the gastrointestinal tract in a water resource.

TABLE IV: WATER QUALITY ANALYSIS OF HUAI LUANG RIVER WITH A SEASONAL VARIATION

Parameter	Summer				Rainy season				Winter			
	Up stream	Mid stream	Down stream	Average	Up stream	Mid stream	Down stream	Average	Up stream	Mid stream	Down stream	Average
Temperature (℃)	30.77 ±2.22	31.87 ±2.00	32.08 ±2.68	31.57 ±1.36	33.41 ±2.27	32.99 ±1.00	33.01 ±2.78	33.14 ±0.89	32.71 ±1.43	33.63 ±0.72	32.71 ±1.96	33.02 ±0.47
pH	7.14 ±0.51	6.76 ±0.66	6.58 ±0.58	6.83 ±0.21	7.27 ±0.36	6.82 ±0.32	6.58 ±0.26	6.89 ±0.17	7.55 ±0.41	7.08 ±0.57	6.77 ±0.48	7.13 ±0.11
DO (mg/L)	4.29 ±0.81	4.09 ±0.80	4.18 ±0.84	4.19 ±0.34	5.42 ±0.85	6.26 ±0.39	5.95 ±0.81	5.88 ±0.24	4.48 ±0.89	4.81 ±0.41	4.37 ±0.42	4.55 ±0.36
BOD (mg/L)	3.16 ±2.29	2.45 ±1.14	2.44 ±2.17	2.68 ±0.88	1.66 ±0.36	0.83 ±0.49	0.69 ±0.50	0.89 ±0.24	2.64 ±0.57	2.16 ±0.11	1.93 ±0.24	2.24 ±0.23
TCB (mg/L)	128,750 ±12,914	106,750 ±13,515	96,750 ±8,951	110,750 ±16,371	72,376 ±10,790	51,150 ±7,227	53,550 ±6,797	59,025 ±6,623	104,125 ±13,717	88,250 ±6,817	89,000 ±5,030	93,792 ±8,957

FCB (mg/L)	22,500 ±3,103	18,688 ±2,628	17,425 2,770	19,538 ±2,642	9,538 ±1,950	8,849 ±1,708	7,569 ±1,408	8,652 ± 1,413	12,925 ±9,413	10,388 ± 1,585	11,638 ± 1,419	11,650 ± 1,269
NH_3 (mg/L)	1.03 ±0.19	0.61 ±0.17	0.51 ±0.18	0.71 ±0.18	0.49 ±0.11	0.39 ±0.13	0.32 ±0.12	0.40 ±0.13	0.86± 0.14	0.98 ±0.16	0.86 ±0.17	0.90 ±0.16

The average monthly concentration of NH_3 showed significantly different values ($p < 0.05$) with a seasonal variation. The highest average NH_3 concentration was measured in the winter (0.90±0.16mg/L), while the lowest NH_3 concentration average was measured in the rainy season (0.40±0.13 mg/L). The average NH_3 concentration was measured in the summer of 0.71±0.1816 mg/L. The maximum NH_3 concentration detected in the summer at the upstream was 1.03±0.19 mg/L, while the minimum NH_3 concertation detected in the winter at the downstream site was 0.32±0.12 mg/L. In the rainy season, the NH_3 concentrations were detected lower than in the other seasons.

C. *WQI Classification*

The surface water quality of the Huai Luang River was calculated and assessed by using the WQI program produced by the Pollution Control Department, Thailand (PCD-WQI). WQI calculation was calculated using five parameters following the website; http://iwis.pcd.go.th/index.php?method=calculate&etc=1681956372255&fbclid=IwAR0cyGAfVgAU7pU-wk-6HsbDvm2x-7ShEqOrjIdbfziUxbyO2bog0-KtWw. Rating of WQI was classified into five ratings (very good, good, medium, bad and very bad). After running the water quality analysis data in the WQI calculation program, as illustrated in Fig. 2 and Fig. 3. The results showed that the lowest WQI concentration usually occurred during the summer (March to June) upstream, compared to the other seasons. The water quality from upstream to downstream sampling sites showed distinct spatial variations and remained unstable. The spatial distribution of the WQI concentration along the Huai Luang River, based on the three sampling sites with the various wastewater sources (domestic, animal farms, and agriculture), also shows considerable variability. Notably, the upstream reaches of the Huai Luang River typically have a lower WQI concentration than the other sites. The water quality of the Huai Luang River was classified as "Bad" in the range of 54-60 scores over the year. According to the results, there was variation in the WQI over the sampling year. The lowest average WQI concentration was detected upstream (55 score), while the highest average WQI concentration was detected downstream (60 score). The average WQI concentration was detected for the midstream with a 59 score. However, all the WQI scores ranged from 31 to 60, classified as "Bad" water quality.

Fig. 3 showed the minor seasonal differences, with the following WQI concentration for each season; summer (54 score), rainy season (57 score), and winter (56 score). The WQI concentration increased from summer to the rainy season and then decreased again from the rainy season to winter. The lowest and highest WQI concentrations occurred in the summer and the rainy season, respectively. These results indicated the ability of the surface water in the Huai Luang River to self-purify. The WQI ranged between 31–60 scores, showing that water can be used for any purpose except for direct drinking. It needs to be professionally treated before drinking; otherwise, it could be harmful. The water resources of the Huai Luang River can only be used for irrigation or industrial cooling. It should not be drunk under any circumstances, even if treated, as there is still a high chance of it containing pollution, which can be fatal. The wastage from the nearest rivers, animal farms, and agriculture activities decreased DO and BOD, causing the water quality to drop significantly. The WQI from midstream to downstream was better compared with the upstream. DO, BOD, coliform (TCB and FCB), and NH_3 were the major factors behind the decreased WQI.

From WQI analysis, the water qualities of the upstream were at a higher bad level than those of the midstream and downstream. Consumption requires a specific or advanced treatment process before use. Meanwhile, the water quality downstream was unacceptable and only suitable for transportation. Therefore, the surface water quality of the Huai Luang River has a few variabilities both spatially between the sampling sites and seasons. The water quality of the Huai Luang River in the rainy season was better than that in the summer and winter, especially downstream. In contrast, the water quality in the upstream summer was at a bad level, worse than that of other seasons. Also, parameters that impact the general water quality were DO, BOD, TCB, FCB, and $NH_{3,}$ was exceeded the limitation of surface water quality standards in Thailand. WQI methods have been widely used for water quality assessment and developed to date with many different versions [10, 12]. According to the previous studies, the results found that most WQI methods had similar structures but the finer details of the main components varied greatly [14, 15]. To develop a reliable WQI method, one needs to follow four steps: (1) Selection of water quality parameters, (2) Determination of sub-indices, (3) Establishing of parameter weights, and (4) Aggregation of sub-index to compute the final values in accordance with previous reports [18, 20]. The development of WQI can determine multipurpose water usage as they are easy to transfer to all application regions based on the international guideline.

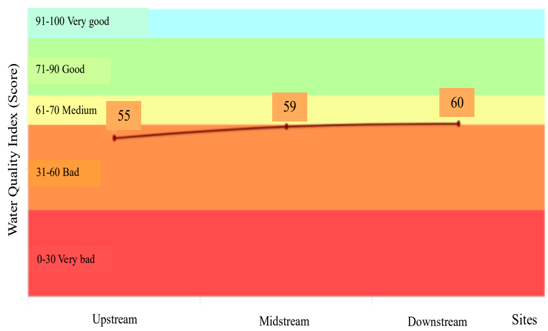

Fig. 2. WQI of the Huai Luang River with various sampling sites.

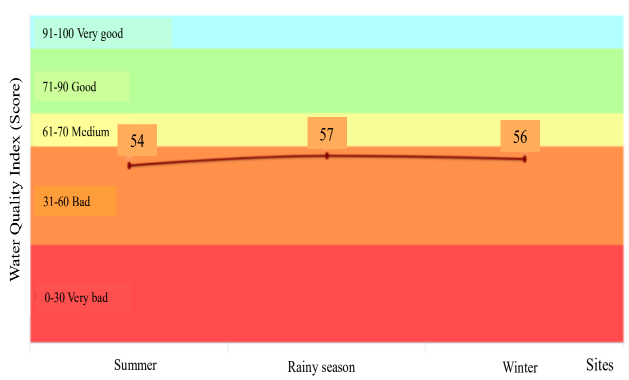

Fig. 3. WQI of the Huai Luang River with seasonal variation.

IV. Conclusion

WQI concentrations in the lake were in the range of 54 to 60 scores. The water quality was found to be bad. Water quality was ranged as Type IV of the PCD surface water resources used for consumption, but requires a water treatment process before use. Seasonal water quality variations existed at each monitoring site along the Huai Luang River. WQI concentration in summer was among the lowest compared to other seasons, indicating the worst water quality status. Marked spatial variation in water quality exists from the upstream reaches to the downstream of the river. Monitoring sites in the upper reaches generally have lower WQI concentrations than those in the lower reaches. Domestic wastewater and animal farm are major sources of the TCB and FCB loading in the river. Domestic wastewater plays a major source role in DO and BOD loading. Agriculture activities play a major source role in the NH_3 loading. The various activities of communities were positively correlated with DO, BOD, TCB, FCB, and NH_3, most of which are at significant or very significant levels. The water quality of the Huai Luang River is mainly affected by point source pollution. Management countermeasures should be taken to control the point sources of water pollution, emphasizing reducing wastewater from municipal sewage, domestic residence, animal farms, and fertilizer of agriculture's inputs into the river. This suggests that many nutrient inputs from the surrounding domestic and agricultural areas could damage the ecosystem's health. Regarding water quality management, WQI is an important aspect data of water resource management. WQI has been widely proposed to qualitatively or quantitatively evaluate the water quality of rivers or lakes including Huai Luang River in Udon Thani. WQI reflects water quality conditions with a numerical score, which makes it easy for the public and the policy makers to understand the condition of an aquatic environment. Therefore, the methodology regarding WQI has come into attention. Besides that, data obtained via assessment and monitoring water quality provides empirical evidence to assist health and environmental decision making. Water quality status from WQI was useful for water management practices that indicator of changes in the physical, chemical or biological composition of the overall water quality.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

S. Phitaktim and S. Wesetsri were mainly responsible for water sampling and laboratory analysis. C. Wangka-orm was conceived the data and analyzed the statistical. T. Togari and S. Sato were advised the research conceptual and methodology. M. Wongaree was performed the data analysis and wrote the paper. All of the authors have approved the final version.

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