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Water Quality Assessment by Using of Water Quality Index for Mak Khaeng Canal, Udon Thani Province, Thailand

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Abstract

This paper investigates the water quality of Mak Khaeng canal in Udon Thani province using the Water Quality Index (WQI) in order to study the water quality assessment. Mak Khaeng canal is the main canal in Mueang Udon Thani district of a municipality. WQI technique was used following the Surface Water Quality Standards of Pollution Control Department, Ministry of Natural Resources and Environment, Thailand (PCD-WQI). The five parameters based on dissolved oxygen (DO), biochemical oxygen demand (BOD), ammonia (NH_3), fecal coliform bacteria (FCB), and total coliform bacteria (TCB) were analyzed to calculate WQI of the canal by the different twelve sampling stations. The result showed the water quality in Mak Khaeng canal is poor in the range. This is because of the inadequacy of the existing sewage systems in Udon Thani city area and untreated wastewater discharged from domestic, school, office, university, markets and commercial sources. Therefore, this research study was expected to present valuable information of WQI for Mak Khaeng canal to water quality management by administrators and community participation of local people.

Keywords: Water quality assessment; Surface water quality; PCD-water quality index; Mak Khaeng canal; Mueang Udon Thani

1. Introduction

Udon Thani province is located in the northeast of Thailand and subdivided into twenty districts, as illustrated in Figure 1. Mueang Udon Thani is a central district of Udon Thani province. It is a large city and serves as a center of transportation and tourism. Moreover, it portrays a land of forest temples, a gateway to Laos and the Indochina countries, and possesses one of the world's ancient civilization sites (Thiamdao and Inthasotti, 2016). The rapid expansion of population and commercial growth with their increasing demands for water use are the major causes of water resource deterioration in urban society (Suttibak *et al*., 2010).

At present, water pollution is one of the most critical environmental problems in Mueang Udon Thani city. The situation will tend to be worse in the future unless proper measures are undertaken. As because of this, the rapid development of economic structure in Udon Thani city area with slow environment

management development has the main effect on natural water resources, animals, and health of human. Therefore, it is necessary to obtain appropriate information to observe the quality of water resource.

Mak Khaeng canal is the main canal passed in Mueang Udon Thani city. It is about 11 kilometers length, 3 meters wide, and 4 meters deep. It is an important waterway in Mueang Udon Thani district. It plays a role as the main water source for many activities including agriculture and domestic affairs. It also received many discharges that result in the deterioration of its water quality (Munna *et al.*, 2013). In addition, this canal is a natural source of wastewater from the drainage of both rain and wastewater municipality, before flowing into the Huay Luang canal. Water quality index (WQI) is the most widely used to analyze and evaluate the overall water quality. It is an effective method to study the quality of water in order to assess its suitability for various uses (Gorde and Jadhav, 2013). WQI was mostly used as a technique to transform the qualities of water characterization data into a single number, which represents the water quality level (Charuvan *et al.*, 2013).

The water quality index of the Pollution Control Department (PCD-WQI) was one of mathematical instrument used to calculate and evaluate the surface water quality for assessment in the river, lake, reservoir, or canal in Thailand (Naubi *et al.*, 2016).

At the present time, it is never been report studied for the quality water assessment of the canal in Mueang Udon Thani city. Therefore, this research aimed to study the level of water condition by using PCD-WQI to evaluate the water quality rating in Mak Khaeng canal in order to compare the pollution level between upstream and downstream at the sampling points.

2. Experimental procedure

2.1 Study area

For the assessment of water quality in Mak Khaeng canal using WQI, the twelve sampling stations were selected covering about 11 kilometers stretch along the course of the canal from November 2017 to February 2018 as shown in Figure 2.

The name and location of different water sampling stations passed in Mueang Udon Thani city were described in Table 1.

2.2 Water quality parameters

The water quality parameter of Mak Khaeng canal was investigated by using PCD-WQI. The water quality parameter of water quality assessment was five parameters namely dissolved oxygen (DO), biochemical oxygen demand (BOD), ammonia (NH_3), fecal

Figure 1. Mueang Udon Thani district location in Udon Thani province, Thailand

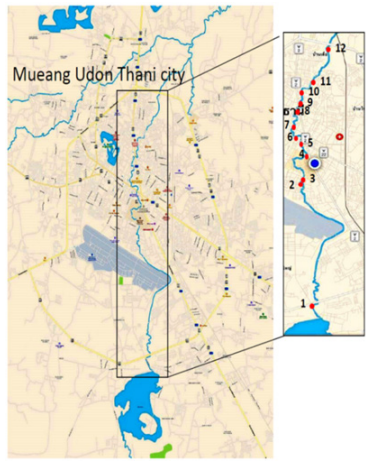

Figure 2. Water sampling stations of Mak Khaeng canal

Table 1. Location and name of water sampling stations in Mak Khaeng canal

Station	Name	Source of wastewater	X	Y
1	Ban Chan Reservoir	Upstream	265746	1920402
2	Phanom Wan	Domestic	265535	1924194
3	Jintakarm	Domestic	265530	1924549
4	Si Suk	School, University	265628	1925286
5	Sisuttha	Commercial, Restaurant	265271	1925885
6	PrajakSillapakom	Commercial, Office	265195	1926164
7	Athipbodi	Office, Restaurant, Market	265227	1926599
8	Phon Phisai	Commercial, Restaurant, Market	265450	1926973
9	Udondutsadi 4	Commercial, Office, School	265498	1927320
10	Phit Narong 1	Domestic	265671	1927442
11	Udondutsadi 6	Domestic	265847	1927663
12	Mak Khaeng Pumping Station	Downstream	266404	1928852

coliform bacteria (FCB), and total coliform bacteria (TCB). These parameters were used to determine the level of water quality in Mueang Khaeng canal, which the main canal passed in Mueang Udon Thani city. Additionally, the water samples were analyzed by twice time per sample and preserved in the field. It was then analyzed by the laboratory following the water analysis standard methods.

2.3 Water quality index (WQI) classifications

After obtained the results of water analysis from above experiment (2.1), the data of water quality from Mak Khaeng canal were calculated and evaluated to determine the quality of surface water in Mak Khaeng canal using the water quality index of Pollution Control Department, Thailand (PCD-WQI) following the website; http://iwis.pcd.go.th/ index.php?method=calculate&etc=1520432561311. The program of the PCD-WQI calculation was described in details by Choo-In *et al.* (2015). The score of PCD-WQI values were classified into four rating (very good, good, poor, bad and very bad), as illustrated in Table 2. Furthermore, the results of water quality analysis of Mak

Table 2. PCD-WQI value and Surface water quality standard of Thailand

WQI value	Score	Surface water quality standard of PCD, Thailand
Very good	**91-100**	**Type 1**: 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.
Good	**71–90**	**Type 2**: 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.
Medium	**61-70**	**Type 3**: Medium clean fresh surface water resources used for consumption, but passing through an ordinary treatment process before using and used for agriculture.
Bad	**31-60**	**Type 4**: Fairly clean fresh surface water resources used for the consumption, but require special water treatment process before using, and used for industry.
Very bad	**0-30**	**Type 5**: The sources which are not the classification in class 1-4 and used for navigation, conditions usually depart from natural or desirable levels.

Khaeng canal was then classified the surface water resources used for the consumption by the type of surface water quality standard of Pollution Control Department, Ministry of Natural Resources and Environment, Thailand (Prakirake *et al.*, 2009)

3. Results and Discussions

3.1 Analysis of water quality of Mak Khaeng canal

The critical of water quality parameters in this study were investigated from five parameters (DO, BOD, NH_3, FCB, and FCB) from November 2017 to February 2018. These parameters of water quality analysis were then used to evaluate by WQI for Mak Khaeng canal assessment. The overall of water quality parameters was analysis followed by the Surface Water Quality Standards of the Pollution Control Department, Ministry of Natural Resources and Environment, Thailand. The water quality data of all the stations were presented and discussed for each parameter, as presented in Table 3.

A high concentration of NH_3 is an important parameter that impacts in Mak Khaeng canal quality. The average of NH_3 concentration was 0.76±0.35 mg/L, which a high in the surface water standard (<0.5 mg/L). This result indicated that the water quality is polluted. These might be the results were caused by a high wastewater from Udon Thani domestic activities into the downstream station in Mak Khaeng canal.

DO was also a parameter of the indicator of the ability of nutrients in the water to support aquatic life. Average concentration of DO was 4.82±1.35 m/L. It could be observed that an average of DO concentration was found over the optimum concentration of DO in water for ensuring healthy aquatic life is 4.0 mg/L (Regmi and Mishra, 2016).

According to the Surface Water Quality Standards (PCD) in Thailand, DO concentrations in surface water as types two or three must not be less than 2 mg/L. More obviously, the sampling water at station 1, namely upstream of Ban Chan reservoir was 7.31±0.33 mg/L. It showed in the highest of DO concentration for the good water quality. These are because the water sampling of station 1 was too far from heavy human activities, hence; the water quality at station 1 was in good. It was indicated that concentration of DO was the main factor for the health of an aquatic life in a canal, which used for a direct consumption. For another water sampling stations in Mak Khaeng canal, the water quality was a lower oxygen concentration that caused

Table 3. Water quality analysis of twelve water sampling stations in the canal

Water sampling station	Water quality analysis (November 2017 – February 2018)					
		DO (mg/L)	BOD (mg/L)	NH_3 (mg/L)	FC (MPN/100ml)	TCB (MPN/100ml)
	Standard	**>2.0**	**<4.0**	**<0.5**	**<4,000**	**<20,000**
1	**Max**	7.64	6.40	0.29	651	1,600
	Min	6.90	0.38	0.21	53	225
	Avg	7.31	2.58	0.26	335	996
	SD	0.33	2.63	0.04	257	711
2	**Max**	7.27	6.50	0.46	16,000	32,000
	Min	6.10	2.55	0.23	1,600	16,000
	Avg	6.70	4.09	0.30	8,800	20,000
	SD	0.50	1.69	0.11	8,314	8,000
3	**Max**	7.32	18.75	0.45	16,000	32,000
	Min	6.50	2.90	0.26	1,600	16,000
	Avg	6.75	7.04	0.35	12,400	24,000
	SD	0.38	7.81	0.08	7,200	9,238
4	**Max**	7.49	26.00	0.66	16,000	32,000
	Min	3.00	4.05	0.44	1,600	16,000
	Avg	4.99	10.99	0.52	12,400	28,000
	SD	2.01	10.17	0.10	7,200	8,000
5	**Max**	7.47	22.00	0.74	32,000	160,000
	Min	2.85	4.70	0.43	16,000	32,000
	Avg	4.53	10.98	0.60	24,000	64,000
	SD	2.02	7.58	0.17	9,238	64,000
6	**Max**	7.52	16.75	1.44	32,000	160,000
	Min	3.25	5.15	0.45	16,000	32,000
	Avg	4.38	9.48	0.83	24,000	88,000
	SD	2.09	5.03	0.45	9,238	53,066
7	**Max**	7.59	26.00	1.57	80,000	160,000
	Min	3.00	5.80	0.36	16,000	80,000
	Avg	4.55	12.70	0.89	40,000	100,000
	SD	2.09	9.04	0.60	27,713	40,000
8	**Max**	7.66	29.00	1.48	80,000	160,000
	Min	0.30	5.10	0.50	32,000	80,000
	Avg	3.79	15.40	0.97	44,000	140,000
	SD	3.03	10.29	0.53	24,000	40,000

Table 3. Water quality analysis of twelve water sampling stations in the canal (continue)

Water sampling station		Water quality analysis (November 2017 – February 2018)				
		DO (mg/L)	BOD (mg/L)	NH_3 (mg/L)	FC (MPN/100ml)	TCB (MPN/100ml)
	Standard	**>2.0**	**<4.0**	**<0.5**	**<4,000**	**<20,000**
9	**Max**	7.59	21.25	1.86	32,000	160,000
	Min	0.95	9.50	0.98	16,000	32,000
	Avg	3.59	12.63	1.40	24,400	88,000
	SD	2.85	5.76	0.48	12,419	53,066
10	**Max**	7.46	16.00	1.49	16,000	80,000
	Min	1.30	4.90	0.42	1,600	32,000
	Avg	3.94	9.58	1.02	8,800	44,000
	SD	2.57	4.64	0.51	8,314	24,000
11	**Max**	7.54	23.50	1.27	16,000	32,000
	Min	0.30	7.50	0.87	1,600	16,000
	Avg	3.63	11.80	1.10	12,400	24,000
	SD	2.98	7.81	0.20	7,200	9,238
12	**Max**	7.53	19.50	1.00	16,000	32,000
	Min	1.00	5.50	0.70	1,600	16,000
	Avg	3.68	9.45	0.87	12,400	20,000
	SD	2.78	6.71	0.13	7,200	8,000
	Average	4.82	9.72	0.76	17,995	53,416

to be a smell bad because of waste products produced by organisms surviving in low oxygen environments. It should be concluded that the decreased in DO concentration in a stream was possibly a result of the high consumption of DO by microorganisms to mineralize dissolved organic matter released from urban (Orozco *et al*., 2017).

On the other hand, a high BOD concentration indicated that the concentration of DO was decreased, with potentially dangerous implications for the biodiversity in Mak Khaeng canal. BOD has been used to determine the strength of oxygen required to stabilize domestic and industrial wastes. It could be observed that the average BOD concentration found to be over surface water standard at 9.73±3.66 mg/L (BOD ≤2.0 mg/L), which showed in the overall of BOD standard for the good water quality. Therefore, it could be concluded that increased BOD demand can be caused by high levels of organic pollution.

The main factors of wastewater problem in Mak Khaeng canal were a wastewater discharged from domestic, market, school, university, office, and commercial sources. When highly organic wastes from untreated wastewater discharged from communities into the canal, it was the main effect for increasing of the microbial activity of the aquatic system, resulting in the escalation of BOD and depletion of DO.

The average of FCB concentration was 17,995 MPN/100 ml (<4,000 MPN/100 ml), which a high concentration likely from wastewater discharged nearby community's areas. It was an important parameter to indicate that the high FCB concentration can lead to the pathogenesis and pathogenesis of the disease which effects to human (Gupta *et al*., 2017).
At last parameter, the detection of coliform bacteria in feces was the result of humans and animals. At present, the average concentration of TCB was not currently specified in Thailand.

TCB of all stations was observed with an average concentration of 53,416 MPN/100 ml (<20,000 MPN/100 ml), which a high concentration likely from wastewater discharged from nearby community's areas. Finally, the results could be concluded that water quality in Mak Khaeng canal was in accordance with the surface water quality standards, the types four of Pollution Control Department, Ministry of Natural Resources and Environment, Thailand.

In addition, the standard values for surface water type's four were found. The results showed that the contaminated canal surface water quality was similar to that of the surface water canals in Thailand (Prakirake *et al*., 2009). In Bangkok, the FCB and TCB communities was a higher than that of the outside of the community. These canals were also contaminated with organic matter and could not be used for pre-disinfection. The importance of water-to-water flows was urban activities, especially wastewater from the point sources, as well as drainage systems from wastewater treatment systems. Other factors that originate from Udon Thani community and agriculture were nonpoint sources, such as rain, flood, human waste, land use, mining, etc.

3.2 Evaluation of Water quality index of Mak Khaeng canal

For evaluation of WQI in Mak Khaeng canal, five parameters were used and described above to calculate and determine the level of water quality. As results, it was mostly rating of bad quality. It was up to the bad rating (score = 46) only November 2017 that fairly clean fresh surface water resources used for the consumption, but require special water treatment process before using, and used for the industry following the surface water quality standard of PCD, Thailand. The scale of PCD-WQI evaluated in this work was 46, 42, 30, and 36 in the month of November 2017 to February 2018, respectively, as shown in Table 4.

More obviously, the BOD concentration was studied in November (rain season) that was lower than BOD which found during December 2017 to February 2018 (dry season). This is effect by season (rain-off) (Singkran *et al*., 2010). The disinfection and improvement process water quality should generally be a warning for use in water conservation, fishing, swimming, and sports.

Moreover, high concentration of FCB and TCB were also exceeded over the standard levels for water quality. This is because coliform bacteria were a risk indicator of contamination. TCB and FCB parameters in excess of PCD water quality standards should have follow-up and follow-up measures to prevent and mitigate the effects by the relevant agencies for the good health and environmental management. For water assessment of Mak Khaeng canal, the score of WQI during November 2017 to December 2018 were presented in Figure 3. The water quality of Mak Khaeng canal has been continuously degraded all along its PCD-WQI standard.

According to surface water in Type four: Fairly clean fresh surface water resources used

Table 4. Water quality index of Mak Khaeng canal

Month	Water quality analysis							Surface water quality Std.
	DO (mg/L)	BOD (mg/L)	NH_3 (mg/L)	FCB MPN/100ml	TCB MPN/100ml	WQI		
	>2.0	<4.0	<0.5	<4,000	<20,000	Score	Value	
Nov, 2017	7.47	5.18	0.52	8,937	30,685	46	Bad	4
Dec, 2017	4.52	6.69	0.57	14,834	46,800	42	Bad	4
Jan, 2018	3.10	19.30	1.00	28,151	86,800	30	Very bad	5
Feb, 2018	4.18	7.72	0.97	20,054	49,379	36	Bad	4
Average	4.82	9.72	0.77	17,994	53,416	39	Bad	4

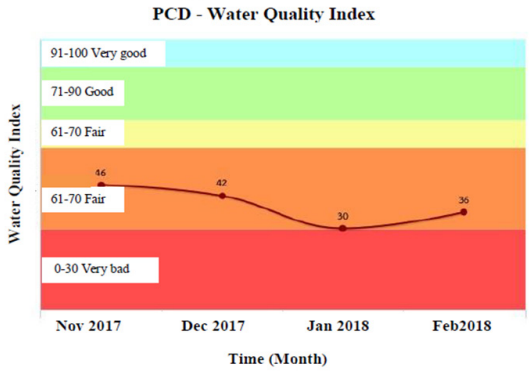

Figure 3. PCD water quality index

for the consumption, but require special water treatment process before using, and used for agriculture. The results were related to the WQI of Mak Khaeng canal that found to be in the range 36 to 46 of scores, denoting bad environmental quality. It could be concluded that WQI rating showed the scale of water quality for all stations was a bad range for water uses. A high wastewater into the canal was discharged from a large residential, school, office and market. The water quality at this location reflects the impact of domestic discharges from Udon Thani city municipality.

More obviously, the minimum PCD-WQI on January 2018 was found at 30 because of the lacking of water flushing, showing the water quality not suitable for recreational use. It showed the very bad quality and unacceptable. Additionally, this result was similar to WQI of Atharbanki River in India that is bad or poor (Shah and Joshi, 2017). The main reasons for the poor river quality are the quantity of wastewater generated from the city and no freshwater flow in the river (Amneera *et al.*, 2013).

4. Conclusions

Water quality level of Mak Khaeng canal using PCD-WQI for water assessment in Mueang Udon Thani district was bad. The surface water of Mak Khaeng canal received directly untreated wastewater from Udon Thani municipality. It could be indicated that level of water quality by WQI in Mak Khaeng canal was bad that main effect to water quality problem. Mak Khaeng canal was being polluted in order to the rapid urbanization, commercial, and other development activities. The important parameters caused to be water polluted were BOD, FCB, and TCB. This is because of the communities live on sides of the canal was high concentration. The results can be presented for the valuable information to administrators to design the water quality management by community participation of Udon Thani local people. In addition to wastewater from the drainage, the canal also received a major load discharged from total sewage treatment capacity was being used in the capital city. Additionally, the insufficient sewage systems and untreated wastewater discharged from domestic, office, school, university, agricultural, and commercial sources were the main factors leading to surface water contamination of the Mak Khaeng canal.

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