Thai Environmental Engineering Journal Vol. 31 No. 3 (2017) : 1-11
www.eeat.or.th

Comparison of Water Quality in Community and Rural Areas in Mekong River, Thailand by Using Water Quality Index

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Abstract

Mekong River is an international river which is being utilized for many purposes such as fishery, human consumption, and agricultural use. The area of this study covered 8 provinces with 18 stations along Mekong River in Thailand namely Chaing Rai, Loei, Nongkai, Bungkan, Nakon Phanom, Mukdahan, Amnatcharoen and Ubon Ratchathani. This study was conducted to compare the water quality between community and rural areas by using Mekong River Commission water quality indices (MRC-WQI). As per the results, water quality in community and rural areas presented similar quality. However, it could be noted that there was different in water quality (between the dry season and the wet season). WQI for the protection of aquatic life (WQI-al) was between classes A to C (Very good to moderate level). WQI for the protection of human health-human health acceptability (WQI-hi) presented the water quality from class A to D (very good to very poor level). WQI for agricultural use (WQI-ag) was class A. WQI-hi and WQI-ag in the wet season was poorer than the dry season due to high BOD, COD, ammonia, and nitrate. Therefore, water treatment is required before water use both in community and rural areas.

Keywords : Water Quality Index; Mekong River; Thailand

Introduction

Mekong River is an international river (about 4,900 km long), which originates from the Tibetan Plateau in China, flowing through Yunnan province and then passing through Burma (part of the Upper Mekong). Then it flows through the Golden Triangle at the border between Thailand and the Lao People's Democratic Republic (Lao PDR). In Thailand, the Mekong flows through Chiang Saen, Chiang Khong District, and Wiang Kaen District, Chiang Rai Province before flowing into Lao PDR. Again, it then flowed into the border between Thailand and Lao PDR. Where, it flows through Loei, Nong Khai, Bungkan, Nakhon Phanom, Mukdahan, Amnat Charoen and Ubon Ratchathani regions. The overall distance the river flows through in Thailand is about 800 km. There are 60 million people or 12 million households live in the Lower Mekong basin

(Cambodia, Laos, Thailand and Viet Nam). Of which 80 % of people rely directly on the river system for their livelihoods [1]. The population growth rate along Mekong River in Thailand is 1-2% which contributes to 15% of residential area and 85% rural area [2]. At present, water in Mekong River is being utilized for many purposes namely, consumption, aquaculture, and farming. Water quality is monitored year around to provide recommendations for water use by Mekong River Commission (MRC).

Currently, there are 8 large hydropower projects in Lao PDR. In the upper Mekong, there are 4 completed construction projects and 2 projects under construction. In the lower Mekong, there are 12 large hydropower development projects. Currently, Xayaburi Dam in Lao PDR is under construction. Based on the studies conducted for water level in the Mekong River in 2014, the water level rise/fall rates and fluctuation have not been associated with climate variability. These fluctuations are attributed to the dams built in China and Thailand during the 1990s and 2000s [3]. Therefore, the affected water level and water quality in the dry season and the wet season needs to be addressed for better water management and utilization. According to the 2013 Lower Mekong regional water quality monitoring report [4], the results present that the pH and dissolved oxygen levels decreased as the Mekong River flowed from upstream to downstream while Chemical Oxygen Demand levels exhibited opposite trends. As such, water quality assessment is essential for water utilization for the community and the rural area which have different water needs. Community area is more concerned with water quality especially for consumptions, whereas rural area requires good water quality for agricultural use and also human consumption. The purpose of this research was to assess water quality in terms of utilization for both the community and rural areas which in turn provides suggestions for water use in Mekong River.

Methodology

There were totally 18 sampling stations along Lower Mekong River Basin which occupy 16 sub-districts in 8 provinces in Thailand. Water sampling was done with twice a year in each season (dry season and wet season). Water sampling in the dry season was done during 28-30 May 2015 and wet season during 8-11 October 2015. The details of sampling point of each sub-districts presented in Figure 1. The study sites can be classified into two main areas; namely community areas (MKCh2, MKL1, MKNh2, MKB1, MKN3, and MKA1) and rural areas (MKCh1, MKL2, MKNh1, MKB2, MKN1, MKN2, MKN4, MKM1, MKM2 MKA2, MKU1, and MKU2). The community areas were defined by population in the area more than 10,000 and population density more than 3,000 capita/km^2. The position of sampling points and the date of water sampling are presented in Table 1. There were 12 parameters using for water quality assessment namely, pH, Temperature, Electrical Conductivity (EC), Ammonia nitrogen (NH_3-N), Dissolved Oxygen (DO), Nitrate (NO_3-N), Total Phosphorous (TP), Chemical Oxygen Demand (COD) Biochemical Oxygen Demand (BOD), Total Solid (TS), Total Suspended Solid (TSS) and Fecal Coliform Bacteria (FCB). The samples were analyzed following methods in the Standard Method for Examination of Water and Wastewater [5]. Water samples were preserved at 4°C. DO, pH, and EC were measured onsite by using handheld devices.

Table 1 Sampling station

Station	Position	Coordinates
MKCh1-A	Rimkong sub-district, Chiangrai	N20.365006 E100.358213
MKCh2-B	Sridonchai sub-district, Chiangrai	N20.213471 E100.453586
MKL1-C	Pakchom Sub-district, Loei	N18.049833 E101.835938
MKL2-D	Paktom sub-district, Loei	N17.842893 E101.567318
MKNh1-E	Kutbong sub-district, Nongkai	N18.129741 E103.081806
MKNh2-F	Pako sub-district, Nongkai	N17.818446 E102.698217
MKB1-G	Bungkha sub-district, Bungkan	N18.282962 E104.009587
MKB2-H	Nhongdean sub-district, Bungkan	N18.337771 E103.954017
MKN1-I	Chaiburi sub-district, Nakhon Phanom	N17.652496 E104.470756
MKN2-J	Donnanghong sub-district, Nakhon Phanom	N17.089441 E104.764839
MKN3-Q	Mueang sub-district, Nakhon Phanom	N17.398300 E104.803300
MKN4-R	Chaiburi bridge, Nakhon Phanom	N17.644256 E104.461791
MKM1-K	Pongkam sub-district, Mukdahan	N16.753701 E104.750537
MKM2-L	Nasrinuan sub-district, Mukdahan	N16.477467 E104.799368
MKA1-M	Chanuman sub-district, Amnatcharoen	N16.377917 E105.022783
MKA2-N	Koksan sub-district, Amnatcharoen	N16.309167 E105.020800
MKU1-O	Naveang sub-district, Ubon Ratchathani	N16.046800 E105.550017
MKU2-P	Sumrong sub-district, Ubon Ratchathani	N16.239833 E105.761267

This study evaluated water quality for utilization for various purposes such as protection of aquatic life, human and agricultural uses, therefore, MRC-WQI [4] was considered in this study. The Water Quality Index for the protection of Aquatic Life (WQI-al) was calculated by using equation 1, six parameters were included which are listed in Table 2.

$$WQI = \frac{\sum_{i=1}^{n} p_i}{M} \times 10 \qquad (1)$$

Where p_i is a point based scored on each sample. If each parameter listed in Table 2 meets its respective target value in Table 2, its corresponding weighting factor was scored; otherwise, a score of zero was assigned, n was the number of samples from the station in the year. M was the maximum possible score for the measured parameters in the year. The classification system for the Water Quality Index for the Protection of Aquatic Life is summarized in Table 3.

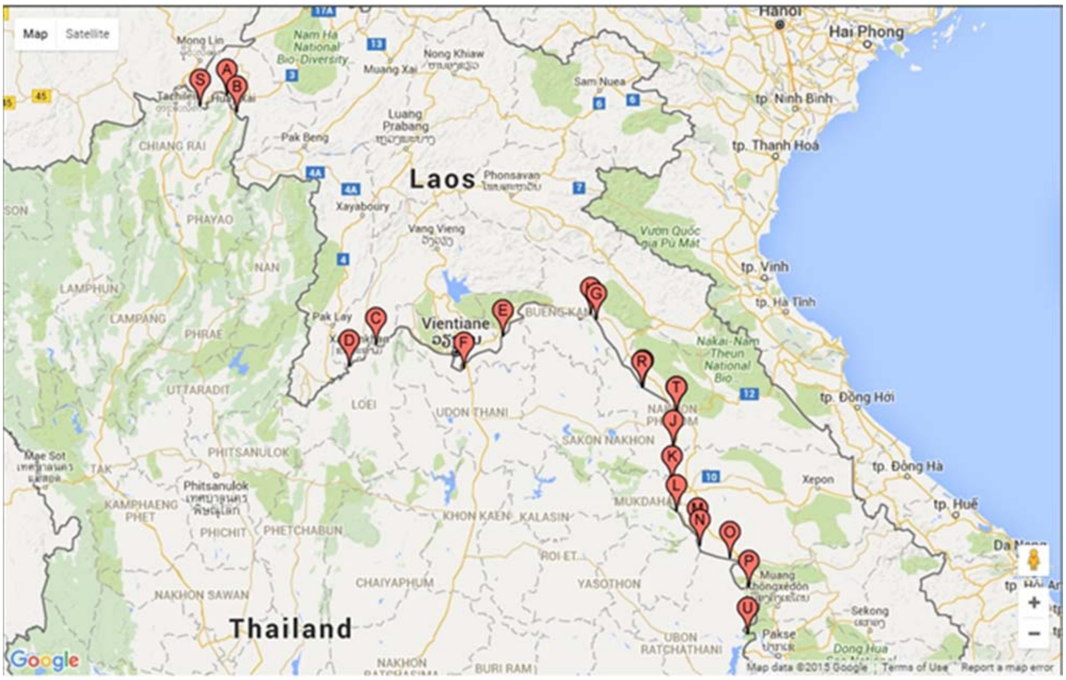

Figure 1 Sampling stations along Mekong River in Thailand

Table 2 Parameters used for calculating the rating score of the Water Quality Index of the Water Quality index for the Protection of Aquatic Life with their target values

Parameters	Target Values
pH	6-9
EC (mS/m)	< 150
NH_3 (mg/L)	0.1
DO (mg/L)	>5
NO_3-N (mg/L)	0.5
T-P (mg/L)	0.13

Table 3 Rating systems for the Water Quality Index for the Protection of Aquatic Life

Rating Score	Class
9.5 ≤ WQI ≤ 10	A: High Quality
8 ≤ WQI ≤ 9.5	B: Good Quality
6.5 ≤ WQI ≤ 8	C: Moderate Quality
4.5 ≤ WQI ≤ 6.5	D: Poor Quality
WQI ‹ 4	E: Very Poor Quality

The Human Acceptability Index utilized parameters of indirect impact, as identified by human health risk index utilizes direct impact parameters. The rating score can be calculated using Equation 2, which was based on the Canadian Water Quality Index [6]. The calculations for the rating for human health acceptability index with their target values are listed in Table 4. The classifications system for the water quality index for the Protection of Human Health-Human Acceptability index (WQI-hi) is summarized in Table 5.

$$WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \quad (2)$$

Where, F_1 is the percentage of parameters which exceed the guidelines and can be calculated by Equation 3. F_2 was the percentage of individual tests for each parameter that exceeded the guideline and can be calculated using Equation 4. F_3 is the extent to which the failed test exceeds the target value and can be calculated by using Equation 5. Where nse is the sum of excursions and can be calculated using Equation 6. Finally, the excursion was calculated by using equation 7.

$$F_1 = \left(\frac{\# \, of failedparameters}{Total \, \# \, of parameters}\right) \quad (3)$$

$$F_2 = \left(\frac{\# \, of failedtests}{Total \, \# \, of tests}\right) \quad (4)$$

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right) \quad (5)$$

$$nse = \left(\frac{\sum excursion}{Total \, \# \, of tests}\right) \quad (6)$$

$$excursion = \left(\frac{failedtestvalue}{guidelinevalue}\right) - 1 \quad (7)$$

Table 4 Parameters used for calculating the rating score of the Water Quality index for the Protection of Human Health-Human Health Acceptability index with their target value

Parameters	Target Values
pH	6-9
EC (mS/m)	< 150
NH_3 (mg/L)	0.5
DO (mg/L)	4
NO_3-N (mg/L)	5
COD (mg/L)	5
BOD (mg/L)	4

Table 5 Rating systems for the Water Quality index for the Protection of Aquatic Life

Rating Score	Class	Description
95 ≤ WQI ≤ 100	A: High Quality	All measurements are within objective virtually all the time
80 ≤ WQI ≤ 95	B: Good Quality	Conditions rarely depart from desirable levels
65 ≤ WQI ≤ 80	C: Moderate Quality	Conditions sometimes depart from desirable level
45 ≤ WQI ≤ 65	D: Poor Quality	Conditions often depart from desirable levels
WQI < 45	E: Very Poor Quality	Conditions usually depart from desirable levels

Water Quality Index for Agricultural Use (WQI-ag) focuses on water quality for general irrigation and paddy rice. The indices for general irrigation and paddy rice were calculated based on water quality guidelines for salinity (electrical conductivity). The degree of consequence for the general irrigation and paddy rice indices are outlined in Table 6.

Table 6 Electrical conductivity guidelines and degrees of consequence for Water Quality index for Agricultural Use-general irrigation and paddy rice

Irrigation Raw Water	Degree of Consequence		
	None (Good)	Some (Fair)	Severe (Poor)
General Irrigation (EC_mS/m)	< 70	70-300	>300
Paddy Rice (EC_mS/m)	< 200	200-480	>480

Results and Discussions

The results presented the comparison of water quality between community area and rural area with 12 parameters. The parameters which represent physical characteristics such as Temperature, EC, TS and TSS. The chemical parameters such as pH, DO, NH_3-N, NO_3-N and T-P. FCB represented biological parameter. COD and BOD indicate the water pollution. The results for community area (MKCh2, MKL1, MKNh2, MKB1, MKN3, and MKA1) are presented with a highlight in each Figure.

Physical Characteristics

As per the results EC was 7.5-37.8 mS/m. implying a good level for aquaculture, agricultural and human consumption when compared with a target value of each WQI. Whereas, TS was 40-583 mg/L and TSS was 2-394 mg/L. TS and TSS were not used for WQI calculation but these parameters can be used to interpret the sediment flow in the river due to water flow and rain. Figure 2 indicates that there was no significant difference between community and rural area for the assessed physical parameters. However, TS and TSS had a difference between the dry and wet seasons. TS and TSS in the wet season (TS 40-583 mg/L, TSS 20-394 mg/L) was observed to be higher than that in the dry season (TS 60-354 mg/L, TSS 2-128 mg/L).

Chemical characteristics

Figure 3 presents the characterization of chemical parameters namely, pH, DO, BOD, COD, Ammonia, Nitrate, and TP. As per the results, the average pH of 18 sampling stations in Mekong River was in the range of 6.6-8.81. DO at each station varied between 5.1-9.2 mg/L. BOD was in the range of 0.06-12 mg/L, while COD was between 3.40-67.2 mg/L. Ammonia concentration varied between 0.1-11.76 mg/L. Nitrate assessment for the 18 sampling stations was in the range of 0.04-3.15 mg/L, while T-P was between 0.01-1.25 mg/L. pH was the parameters utilized for WQI calculation. pH and DO of Mekong River were in the target value for WQI-al and WQI-hi, whereas BOD at some point was over the target value of WQI-hi (4 mg/L). Moreover, COD at the 18 sampling stations was over the target value (5 mg/L). In terms of nutrient in the river, ammonia nitrogen and nitrate were at high levels, which affect the WQI-al calculation. On the other hand, T-P was lower than target value except for MKch1 and MKch2 station. As the result, chemical characteristics did not have a significant difference between residential and rural areas. However, the comparison between the dry season and the wet season presented the different in BOD, COD, and ammonia nitrogen in the river. The comparison of BOD in the dry season and the wet season showed that the dry season had higher BOD (0.06-12 mg/L) than the wet season (0.54-4.05 mg/L). In contrast, COD and ammonia in the dry season were lower than the wet season because, during the wet season, rain and currents washed more sediment and pollutants which were difficult to be degraded within a short time frame.

Biological Characteristic

Fecal Coliform Bacteria in 18 sampling stations were between 28-1600 MPN/100 mL. As presented in Figure 3, the community area has higher FCB than in the rural area. FCB was not used for WQI calculation though. But in any case, it is an important parameter which can help to evaluate the effects of wastewater from human activities along Mekong River.

WQI for the protection of aquatic life

As the results of water quality index for the protection of aquatic life, it represented that water quality in community area and rural area was not different. Water quality index was classified to between class A to C (Very good to moderate level) as presented in Figure 4. These values are acceptable for aquatic life. However, water quality in wet season was poorer than dry season at some point. Ammonia nitrogen and nitrate were the major pollutant which created the problem for aquatic life. However, water quality was sufficient for fishery or aquaculture.

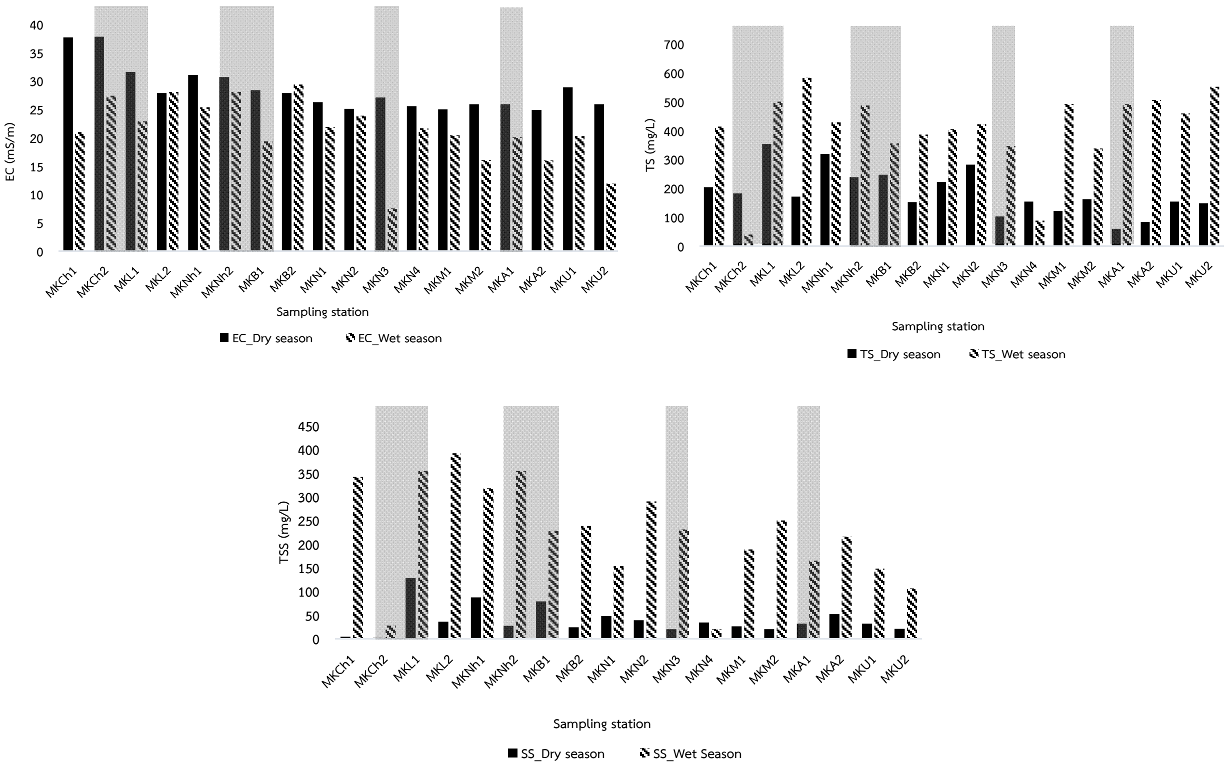

Figure 2 Physical characteristics of 18 sampling stations in Mekong River

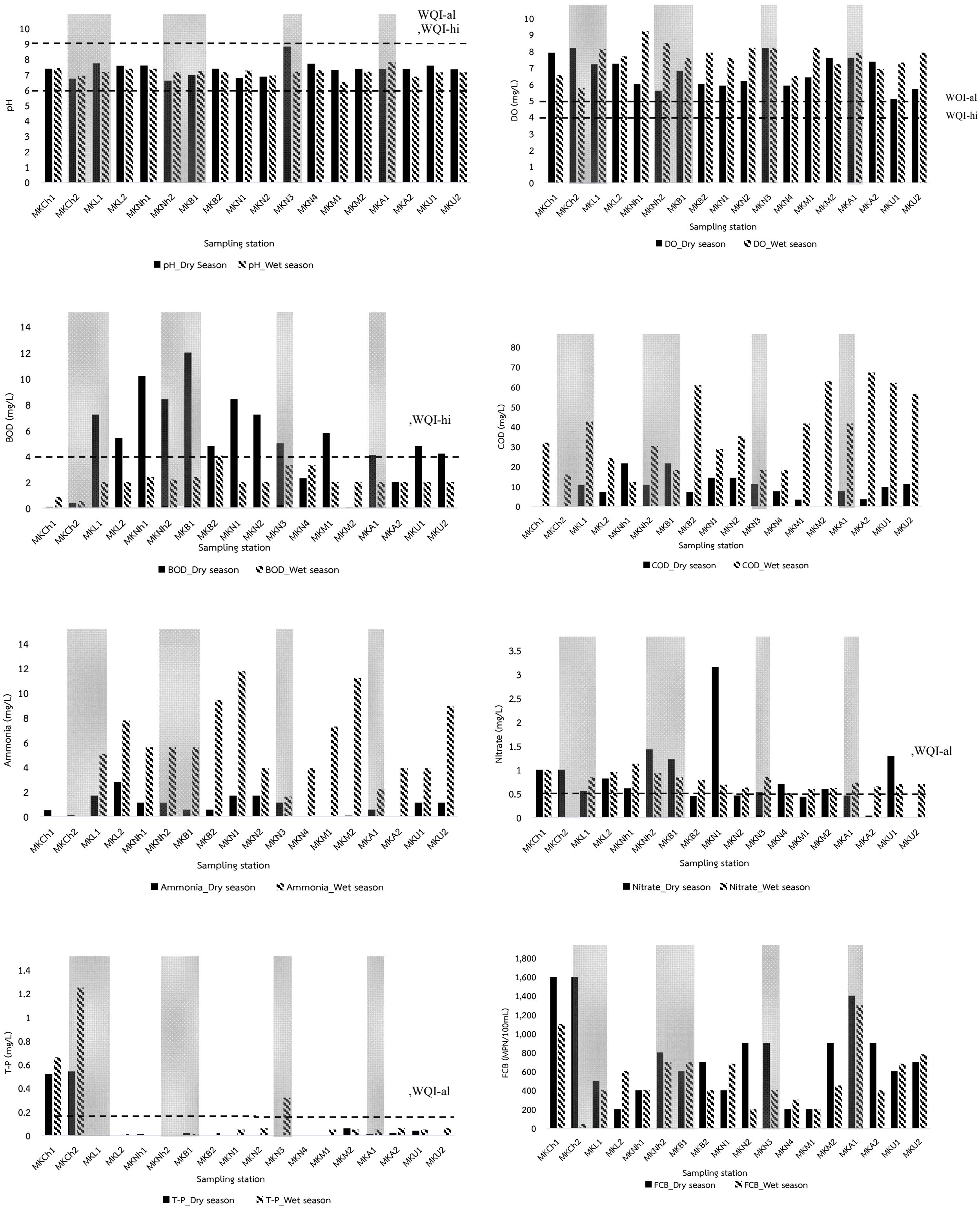

Figure 3 Chemical and Biological characteristics of 18 sampling station in Mekong River

WQI for the protection of human health-human health acceptability

Figure 5 presents the comparison of water quality index for the protection of human health with a focus on human acceptability. The assessment indicates the water quality was between class A to class D (best level to the worst). Implying the WQI varied across the whole range. Differences between inhabited areas and non-inhabited ones were not significant. However, water quality during the dry season was better and poor during the wet season. Under normal conditions, water pollution should be diluted in the wet season, but due to dams build on the Mekong River's the flow of water is controlled; resulting in deteriorated quantity. Therefore, It should be noted that the water level in the Mekong River was not natural [7]. In this study, COD was over the target value of WQI-hi and BOD was higher than target value at some point. As the results, water in Mekong River should be properly treated before using for water consumption. Water treatment plants are required to treat water at every discharge point in Mekong River.

WQI for agricultural use

Water quality index for agricultural use was evaluated by electrical conductivity (EC). It was lower than target value in WQI-ag (< 70 mS/m). As the results, WQI-ag were in Class A which is very good level as presented in Figure 6. The water in the assessed areas can be deemed suitable for irrigation and paddy field.

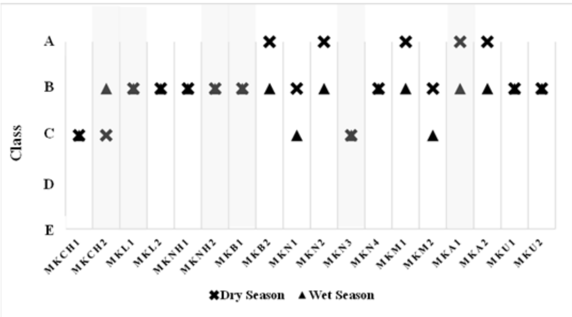

Figure 4 Results of water quality index for the protection of aquatic life

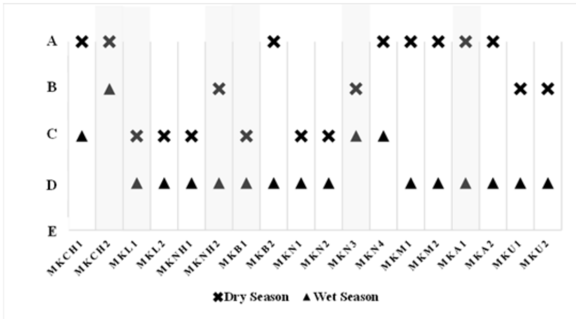

Figure 5 Results of water quality index for the protection of human health with a focus on human acceptability

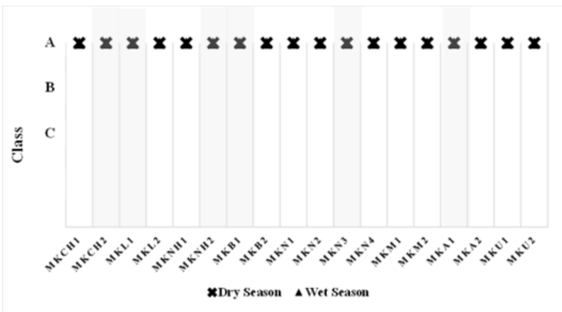

Figure 6 Results of water quality index for agricultural use

The results of WQI-al, WQI-hi and WQI-ag in studied areas were compared with WQI which were monitored yearly by MRC during 2009-2014 [8]. There are 3 sampling stations in Thailand which were monitored by MRC namely Chiang Sean in Chiangrai province, Nakhon Phanom province and Khong Chiam in Ubon Ratchathani province as presented in Table 7. However, this study used a different method for WQI calculation from MRC during 2009-2012. The sampling station of MRC and this study was different but however; the results of WQI from MRC during 2013-2014 can provide the trend of WQI with this study (in 2015). As the results, WQI for the protection of aquatic life and WQI for the protection of human health-human health acceptability presented the water quality in Mekong River is becoming poor. This deterioration in water quality is due to the population increase along Mekong River, where villages and towns have expanded to cities. Moreover, wastewater discharged into the Mekong River was untreated. Regardless, the water quality for agricultural use for MRC and this study was considered very good.

Table 7 The comparison of water quality index of the Mekong River between MRC and this study

Sampling station	2009	2010	2011	2012	2013	2014	2015 (Current study)
WQI-al							
Chiang Sean, Chiangrai	B	B	A	B	B	A	B to C
Nakhon Phanom	A	B	A	B	B	A	A to C
Khong Chiam, Ubon Ratchathani	A	A	A	A	B	B	B
WQI-hi							
Chiang Sean, Chiangrai	B	B	A	B	B	B	A to B
Nakhon Phanom	B	B	B	B	B	B	B to D
Khong Chiam, Ubon Ratchathani	B	A	B	B	B	B	B to D
WQI-ag							
Chiang Sean, Chiangrai	A	A	A	A	A	A	A
Nakhon Phanom	A	A	A	A	A	A	A
Khong Chiam, Ubon Ratchathani	A	A	A	A	A	A	A

Note: The sampling stations of MRC in Thailand and this study were different and method for WQI calculation were also different with the WQI in 2009-2012

Conclusion

There was no significant difference in water quality in community and rural areas. However, water quality during wet and dry seasons was clearly different for water quality index for the protection of human health with a focus on human acceptability. This will have an impact on water consumption, especially community areas that are residential areas now. Water treatment plant should be constructed to improve water quality. There were no differences in the use of aquaculture and agriculture. Water quality in the dry season was better than in the wet season due to the control in flow with the dams upstream. This has resulted in uneven water levels in the Mekong

River and has resulted in present water quality. Therefore, we need to have warning systems installed for water quality utilization along Mekong River. Moreover, governments should also focus on awareness programs to promote pollution prevention in the river.

Acknowledgement

The authors are indebted to Mekong Mainstream Monitoring Project, Kasetsart University Bangken Campus and Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus.

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