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MICROBIOLOGICAL AND PHYSICO-CHEMICAL PROPERTIES OF THE CHI RIVER, MAHA SARAKHAM PROVINCE, THAILAND

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ABSTRACT: Water contamination, particularly microbiological contamination, has been an emerging problem that influences human health. This research aimed to assess the pathogenic contamination of the Chi River in Maha Sarakham Province, Thailand. Surface water samples were collected bi-monthly from January to December 2016 from six stations along the river. Total coliform and faecal coliform bacteria, which are pathogenic index bacteria, were enumerated using the multiple-tube fermentation approach. The results indicated that levels of total coliform and faecal coliform bacteria were in the range of less than $4x10^2$ to $9x10^3$ MPN/100 ml. Of the 72 collected samples, 9 from a station possessed faecal coliform levels that exceeded the water quality standards according to the Thailand National Environment Standard for consumption and agricultural water. Furthermore, the physico-chemical qualities of the water samples were as follow: water temperature ranged from 21.20 to 34.17 ºC, pH ranged from 6.8 to 10.03, DO ranged from 2.51 to 9.82 mg/L, BOD ranged from 1.10 to 6.07 mg/L, NO_3-N ranged from 0.30 to 1.13 mg/L, and PO_4^{-3}-P ranged from 0.08 to 0.47 mg/L. According to the Thailand National Environment Standard for consumption and agricultural water, 21 samples from all stations, 8 samples from 2 stations and 64 samples from all stations did not comply to the criteria of pH, DO and BOD, respectively. In conclusion these findings demonstrated that the Chi River in Maha Sarakham had been contaminated and must be intensively managed and improved before human consumption.

Keywords: Coliform bacteria, Faecal coliform, The Chi River, Surface water quality

1. INTRODUCTION

The Chi River is one of the principal rivers of northeastern Thailand. The total length of the Chi River is 765 km, and it is recognized as the longest river in the country. The river originates in the Phetchabun Mountains Ranges and flows through Chaiyaphum, Nakhon Ratchasima, Khon Kaen, Maha Sarakham, Kalasin, Roi Et, Yasothon, Ubon Ratchathani and Sri Sa Ket Provinces of Thailand. However, 60 km of the river flows through Maha Sarakham Province across Muang, Kosum Phisai and Kantharawichai districts. At least six irrigation projects have been established along the river in Maha Sarakham, and these projects function as the water sources for domestic, agricultural and industrial utilities. Interestingly, the consumption of water in Muang and Kosum Phisai depends on the water from this river [1]. Thus, assessments of the microbiological and physico-chemical parameters are important to ensure safety prior to using water.

Coliform bacteria are a large group of various bacteria species, including both faecal coliform bacteria and non-faecal coliform bacteria. Regulatory levels of coliforms in water for consumption have been established. Consequently, the determination of coliforms plays a major role in the control of water quality [2-4]. The presence of faecal coliform bacteria indicates contamination of the water body by human and/or animal faecal material [5-7]. The occurrence of *Escherichia coli* in water may show the possible existence of disease-causing pathogens such as bacteria, viruses, and parasites [8-10]. Additionally, temperature, pH, DO, BOD, NO_3-N and PO_4^{-3}-P are also important parameters for evaluating water quality [11].

Despite the essential role of the Chi River for domestic utilization, this research aims to evaluate the microbiological and physico-chemical properties of the water from different stations along Maha Sarakham Province. The findings provide information for water management and sustainable utilization in the future.

2. MATERIALS AND METHODS

2.1 Sample Collection

There were six sampling stations, namely, Kok, Kosum Phisai (S01, 16°20.869" N 102°57.770" E), Loeng Tai, Kosum Phisai (S02, 16°12.941"N 103°07.864"E), Tha Khon Yang, Kantharawichai (S03, 16°13.965" E 103°16.124"E), Koeng, Muang Maha Sarakham (S04, 16°13.003" N 103°20.438" E), Muang, Muang Maha Sarakham (S05, 16°14.017" N 103°25.846" E) and Tha Tum,

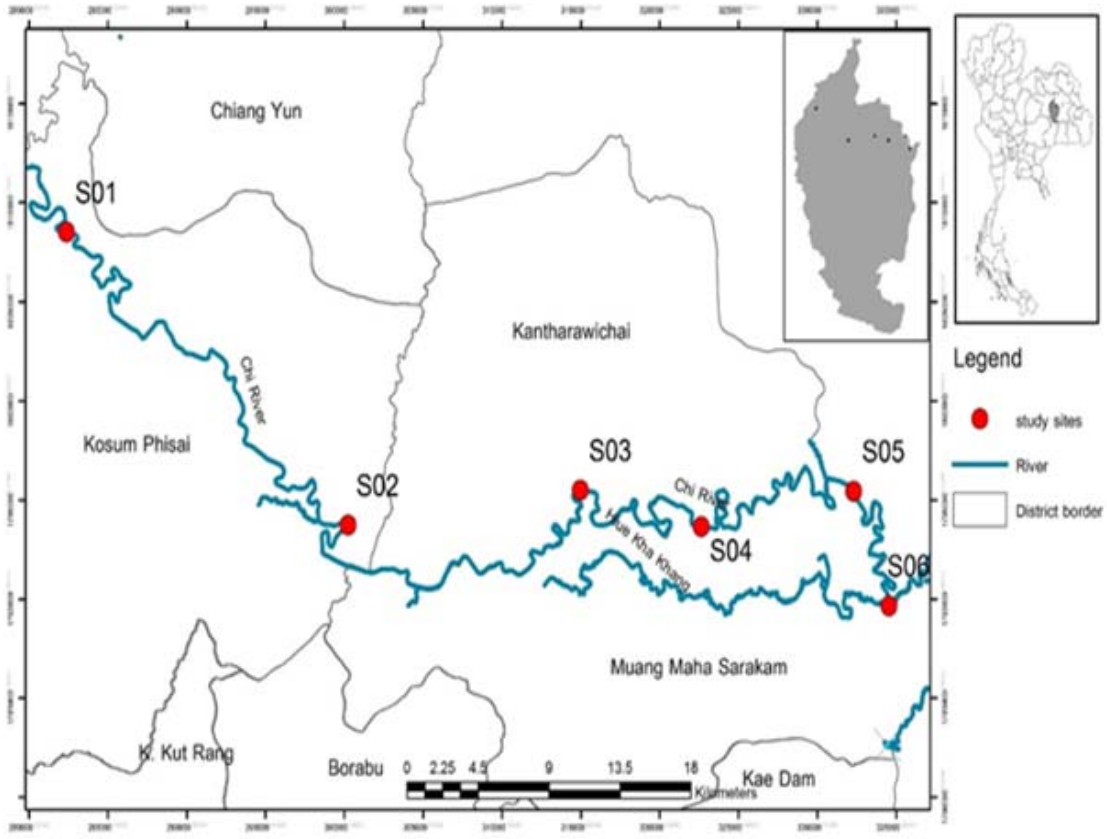

Fig. 1 Sampling stations at the Chi River in Maha Sarakham Province [12]

Muang Maha Sarakham (S06; 16°10.888" N 103°27.131" E) along the Chi River in Maha Sarakham Province (Fig. 1).

Water samples were separately collected at the littoral and limnetic zones of each bimonthly from January-December 2016. One litre of each sample was taken at a depth of 50 cm from the water surface using a water sampler and then transferred to a sterile water bottle. The water bottle was kept in a cooling box and transported to a laboratory at the Faculty of Science and Technology, Rajabhat Maha Sarakham University. All the water samples were stored at 4°C and analysed within 24 hr.

2.2 Microbiological Analysis

The microbiological analysis was focused on a hygiene indicator by counting coliform bacteria in water samples. The most likely number approach was used for total and faecal coliform enumeration. The number of positive tubes was compared to a standard most probable number chart that was expressed in the terms MPN/100 ml.

2.3 Physico-Chemical Analysis

The physico-chemical properties of the water samples, including temperature and pH, were measured directly at the sampling stations using portable electronic metres. Concentrations of NO_3-N and PO_4^{-3}-P were analysed according to the method of FAO (2009) [13-15] in the laboratory.

Dissolved oxygen analysis was carried out using a DO metre. Two bottles of each water sample were set, one bottle was for DO analysis at day 0, and another bottle was incubated at 20°C for five days.

Data obtained from microbiological and physico-chemical analyses were compared to Thailand National Environment Act 1980, Surface Water Quality Standard (class III), water quality for consumption and agriculture.

3. RESULTS AND DISCUSSION

3.1 Microbiological Analysis

A total of 72 water samples collected from the Chi River located in Maha Sarakham Province were analysed for total coliform and faecal coliform. The results are presented in Table 1 and Table 2. The total coliform concentrations over the year ranged from $1.20x10^3$ to $6.25x10^3$ MPN/100 ml, which complied

with the Thailand National Environment Standard for consumption and agricultural water of < $2x10^4$ MPN/100 ml. On the other hand, faecal coliform concentrations ranged from $4x10^2$ to $9x10^3$ MPN/100 ml. Approximately 13% of the water samples possessed faecal coliform concentrations exceeding the Thailand National Environment Standard for consumption and agricultural water of <$4x10^3$ MPN/100 ml. For consumption purposes, the Chi River water requires some water treatments to reduce the biological risks to human health.

The presence of faecal coliform in water indicates human and animal faecal contamination [4]. Humans can be exposed to pathogens from poorly managed animal faeces, particularly in communities where animals live near humans [16]. In this study, most households had been observed animal waste in their living environment at the time of sampling. The lack of animal waste management and movement restriction leads to individual and community-level exposure to animal faeces and potential exposure [4].

3.2 Physico-Chemical Analysis

Physico-chemical analysis of the water samples is shown in Table 3. The water temperature varied from 21.20 to 34.17 ºC. The maximum temperature and minimum temperature of water collected from each sampling station were found in the summer (May) and in the late rainy season (September), respectively.

The water pH values were between 6.84 and 10.03. Of the total water samples, 29% showed pH values out of the range 5 to 9 of the Thailand National Environment Standard for consumption and agricultural water. Approximately 31% of the water samples showed pH values beyond the suitable range of 6.5 to 8.5 according to Thailand Industrial Standard No. 257-2006. In addition, approximately 38% of the water samples had pH values far from the range of 7.0 to 8.5 of the WHO standard [17] for drinking water. The results show that most of the exceeded pH values were found in winter (January) and late winter (March); however, the maximum pH for each sampling station was only found in March.

The DO concentrations varied from 2.51 and 9.82 mg/L. According to the Thailand National Environment Standard for consumption and agricultural water, the minimum DO concentration is 4 mg/L. In this study, the DO concentrations of approximately 11% of the water samples did not comply with the standard. The unusual DO concentrations were primarily found in samples collected from stations S01 and S02 in March.

The BOD concentration ranged from 1.10 to 6.07 mg/L. According to the Thailand National Environment Standard for consumption and agricultural water, the maximum BOD concentration is 2 mg/L. Of the total water samples, approximately 89% did not comply with the standard. Interestingly, unusual BOD concentrations were found in water samples collected from all the stations, and the maximum concentration for each station was in March. The high BOD over the year may caused by a large amount of organic matter originated from domestic wastewater or agricultural activities.

Nitrate concentrations ranged from 0.30 to 1.13 mg/L, which comply with the Thailand National Environment Standard for consumption and agricultural water of 5.0 mg/L and WHO standard of 50 mg/L. Similarly, the obtained phosphate concentrations ranging from 0.08 to 0.47 mg/L were less than the Thailand National Environment Standard for consumption and agricultural water of 0.6 mg/L.

Table 1 Total coliform water samples collected from the Chi River in Maha Sarakham Province

Sampling site		Total coliform (MPN/100 ml)					
		Jan	Mar	May	July	Sept	Nov
S01	Littoral zone	$6.10x10^3$	$5.98x10^3$	$5.70x10^3$	$5.69x10^3$	$5.64x10^3$	$5.50x10^3$
	Limnetic zone	$6.24x10^3$	$6.04x10^3$	$5.64x10^3$	$5.74x10^3$	$5.50x10^3$	$5.64x10^3$
S02	Littoral zone	$4.24x10^3$	$4.10x10^3$	$4.20x10^3$	$3.76x10^3$	$4.38x10^3$	$4.25x10^3$
	Limnetic zone	$4.19x10^3$	$4.14x10^3$	$4.56x10^3$	$3.43x10^3$	$4.50x10^3$	$4.56x10^3$
S03	Littoral zone	$5.40x10^3$	$5.30x10^3$	$5.40x10^3$	$3.23x10^3$	$3.78x10^3$	$6.10x10^3$
	Limnetic zone	$5.24x10^3$	$5.36x10^3$	$5.35x10^3$	$3.20x10^3$	$3.70x10^3$	$6.25x10^3$
S04	Littoral zone	$3.04x10^3$	$3.82x10^3$	$3.30x10^3$	$2.78x10^3$	$2.90x10^3$	$3.76x10^3$
	Limnetic zone	$3.19x10^3$	$3.79x10^3$	$3.24x10^3$	$2.60x10^3$	$2.82x10^3$	$3.50x10^3$
S05	Littoral zone	$2.84x10^3$	$2.94x10^3$	$2.40x10^3$	$2.20x10^3$	$1.90x10^3$	$2.78x10^3$
	Limnetic zone	$2.70x10^3$	$2.89x10^3$	$2.35x10^3$	$2.00x10^3$	$1.60x10^3$	$2.54x10^3$
S06	Littoral zone	$2.01x10^3$	$2.50x10^3$	$2.10x10^3$	$1.50x10^3$	$1.20x10^3$	$2.50x10^3$
	Limnetic zone	$2.39x10^3$	$2.00x10^3$	$1.98x10^3$	$1.28x10^3$	$1.24x10^3$	$2.24x10^3$

Table 2 Faecal coliform water samples collected from the Chi River in Maha Sarakham Province

Sampling site		Faecal coliform -MPN/100 m					
		Jan	Mar	May	July	Sept	Nov
S01	Littoral zone	4.90x10^3	4.30x10^3	4.60x10^3	4.60x10^3	3.70x10^3	3.10x10^3
	Limnetic zone	4.60x10^3	3.10x10^3	4.30x10^3	4.30x10^3	3.30x10^3	2.56x10^3
S02	Littoral zone	3.30x10^3	2.70x10^3	2.66x10^3	2.20x10^3	2.20x10^3	2.13x10^3
	Limnetic zone	3.10x10^3	2.60x10^3	2.20x10^3	1.70x10^3	1.83x10^3	1.70x10^3
S03	Littoral zone	3.10x10^3	2.60x10^3	2.56x10^3	1.30x10^3	1.70x10^3	3.30x10^3
	Limnetic zone	2.30x10^3	2.20x10^3	2.10x10^3	1.10x10^3	1.30x10^3	3.10x10^3
S04	Littoral zone	2.96x10^3	1.70x10^3	2.60x10^3	1.50x10^3	1.70x10^3	2.35x10^3
	Limnetic zone	2.90x10^3	1.30x10^3	1.70x10^3	1.70x10^3	1.30x10^3	2.10x10^3
S05	Littoral zone	1.70x10^3	1.90x10^3	1.60x10^3	1.20x10^3	9.0x10^2	1.20x10^3
	Limnetic zone	1.30x10^3	1.60x10^3	6.0x10^3	9.0x10^3	7.0x10^2	1.70x10^3
S06	Littoral zone	1.10x10^3	1.40x10^3	8.0x10^2	6.0x10^2	4.0x10^2	1.30x10^3
	Limnetic zone	1.10x10^3	1.40x10^3	7.0x10^2	5.0x10^2	4.0x10^2	1.10x10^3

Table 3 Physico-chemical properties of water samples collected from the Chi River in Maha Sarakham Province

Sampling site		Parameter	Month					
			Jan	Mar	May	July	Sept	Nov
S01	Littoral	T (ºC)	24.00	28.90	30.53	25.00	21.00	27.50
	zone	pH	8.22	9.28	7.53	7.03	6.84	7.26
		DO (mg/L)	2.51	2.76	4.06	7.78	6.84	4.10
		BOD (mg/L)	3.67	5.90	4.27	3.60	2.75	3.90
		NO_3-N (mg/L)	0.65	0.63	1.10	0.70	0.71	0.77
		PO_4^{-3}-P(mg/L)	0.23	0.25	0.26	0.26	0.38	0.26
	Limnetic	T (ºC)	24.00	29.43	30.57	25.00	21.20	27.50
	zone	pH	8.40	9.38	7.43	7.03	6.84	7.24
		DO (mg/L)	2.88	2.00	3.80	7.79	6.84	4.20
		BOD (mg/L)	3.37	5.40	4.45	3.80	2.15	3.80
		NO_3-N (mg/L)	0.60	0.53	1.13	0.60	0.68	0.73
		PO_4^{-3}-P(mg/L)	0.37	0.27	0.23	0.35	0.30	0.38
S02	Littoral	T (ºC)	25.33	30.00	31.97	25.00	22.10	27.00
	zone	pH	8.61	9.76	7.67	6.93	7.01	7.30
		DO (mg/L)	6.48	3.62	4.03	8.08	7.01	4.45
		BOD (mg/L)	2.47	6.03	4.07	3.63	2.55	3.25
		NO_3-N (mg/L)	0.60	0.70	0.97	0.63	0.77	0.77
		PO_4^{-3}-P(mg/L)	0.23	0.14	0.25	0.08	0.28	0.34
	Limnetic	T (ºC)	25.76	30.00	32.00	25.00	22.10	27.50
	zone	pH	9.13	9.34	7.80	6.90	7.02	7.30
		DO (mg/L)	6.29	3.75	4.13	8.08	7.02	4.50
		BOD (mg/L)	2.57	6.07	4.27	3.15	2.85	3.20
		NO_3-N (mg/L)	0.50	0.77	1.05	0.53	0.75	0.73
		PO_4^{-3}-P(mg/L)	0.26	0.14	0.26	0.10	0.28	0.37
S03	Littoral	T (ºC)	26.00	30.00	34.00	26.00	22.40	27.50
	zone	pH	9.12	9.65	7.57	7.23	6.89	7.30
		DO (mg/L)	6.03	6.60	5.54	7.61	6.89	3.90
		BOD (mg/L)	1.93	4.57	2.88	2.55	2.50	3.30
		NO_3-N (mg/L)	0.60	0.67	0.70	0.70	0.87	0.93

Sampling site		Parameter	Month					
			Jan	Mar	May	July	Sept	Nov
		PO_4^{-3}-P(mg/L)	0.12	0.19	0.12	0.21	0.33	0.47
	Limnetic	T (ºC)	26.00	30.00	33.00	26.00	22.40	27.50
	zone	pH	9.24	9.40	7.77	7.21	6.89	7.30
		DO (mg/L)	5.99	6.60	6.14	7.60	6.89	4.00
		BOD (mg/L)	2.73	3.88	2.43	2.55	2.50	3.25
		NO_3-N (mg/L)	0.50	0.77	0.83	0.57	0.93	0.83
		PO_4^{-3}-P(mg/L)	0.20	0.17	0.12	0.20	0.30	0.45
S04	Littoral	T (ºC)	27.20	27.00	34.00	27.00	27.80	27.00
	zone	pH	9.50	9.41	8.03	7.67	7.06	7.36
		DO (mg/L)	6.36	7.13	5.76	7.92	7.06	4.20
		BOD (mg/L)	2.50	3.53	3.08	3.55	2.55	3.90
		NO_3-N (mg/L)	0.45	0.60	0.60	0.67	0.94	0.80
		PO_4^{-3}-P(mg/L)	0.11	0.112	0.07	0.11	0.25	0.45
	Limnetic	T (ºC)	26.83	27.67	34.00	27.00	27.80	27.00
	zone	pH	9.63	9.60	8.00	7.67	7.05	7.36
		DO (mg/L)	6.37	7.33	6.15	7.90	7.05	4.25
		BOD (mg/L)	2.90	3.73	3.53	3.65	2.45	3.95
		NO_3-N (mg/L)	0.45	0.57	0.67	0.40	0.95	0.80
		PO_4^{-3}-P(mg/L)	0.19	0.13	0.08	0.19	0.24	0.45
S05	Littoral	T (ºC)	27.07	29.47	33.67	27.00	25.90	27.00
	zone	pH	9.72	9.90	8.03	7.54	7.24	7.50
		DO (mg/L)	7.41	7.42	5.92	7.30	7.24	4.30
		BOD (mg/L)	1.93	2.88	3.43	3.00	1.90	3.10
		NO_3-N (mg/L)	0.40	0.43	0.60	0.50	0.87	0.63
		PO_4^{-3}-P(mg/L)	0.13	0.31	0.15	0.08	0.18	0.37
	Limnetic	T (ºC)	26.00	28.53	34.00	27.00	25.90	27.00
	zone	pH	9.75	9.78	8.03	7.53	7.24	7.45
		DO (mg/L)	7.48	7.45	6.27	7.30	7.24	4.30
		BOD (mg/L)	1.10	3.07	3.30	3.25	1.40	3.00
		NO_3-N (mg/L)	0.40	0.43	0.60	0.40	0.71	0.67
		PO_4^{-3}-P(mg/L)	0.12	0.23	0.16	0.12	0.16	0.39
S06	Littoral	T (ºC)	26.00	29.17	34.17	28.00	27.10	27.00
	zone	pH	9.62	10.03	7.73	7.43	7.21	7.45
		DO (mg/L)	7.23	7.45	5.32	9.82	7.21	6.20
		BOD (mg/L)	2.03	3.63	2.57	2.45	1.26	2.80
		NO_3-N (mg/L)	0.40	0.57	0.50	0.40	0.48	0.53
		PO_4^{-3}-P(mg/L)	0.16	0.40	0.14	0.15	0.13	0.23
	Limnetic	T (ºC)	26.00	29.00	34.00	28.00	27.10	27.00
	zone	pH	9.81	10.00	7.80	7.42	7.20	7.45
		DO (mg/L)	7.41	7.43	5.01	9.80	7.20	6.25
		BOD (mg/L)	1.00	3.63	2.53	2.20	1.20	2.90
		NO_3-N (mg/L)	0.30	0.53	0.50	0.40	0.48	0.57
		PO_4^{-3}-P(mg/L)	0.15	0.40	0.15	0.21	0.14	0.26

4. CONCLUSION

The microbiological and physico-chemical analyses of water samples from the Chi River in Maha Sarakham Province indicated that the water river are not suitable for consumption. The findings show the possible relation between the season and water quality. Moreover, water contamination according to hygiene indicators as well as some unusual physico-chemical parameters suggest that the Chi River in Maha Sarakham Province had been contaminated and must be managed and improved intensively for the purpose of human consumption.

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