Assessment of Surface Water Quality for Sustainable Water Management in Samut Songkram Province, Thailand

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Abstract—This research aimed to analyze surface water quality in Samut Songkram Province, Thailand in order to propose sustainable management plan. Water samples were collected from 217 sampling sites during 3 seasons from December 2011 to August 2012. The results of this study reveal that prominent parameters such as temperature, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrogen compounds in Nitrate and Ammonia and Fecal Coliforms Bacteria were lower than the standard (Class III) of Pollution Control Department, Ministry of Natural Resources and Environment. However, the concentration of heavy metals including lead, cadmium, copper and zinc compounds were higher than the standard. In addition, total value of Total Dissolved Solid (TDS) and turbidity were also higher but cannot be compared with any standard due to a lack of national standard for those parameters.

Appropriate guidelines and management of surface water quality for sustainable water management including: (1) strongly support mitigations plan to reduce water pollution from point source (2) provide collective management of waste water before discharging into water bodies and support campaign for the Corporate social responsibility (CSR), and (3) set up the water quality monitoring stations in each district. Last but not least, the government should prepare an integrated water quality management plans with building a collaborative teams among local government administrations, private sectors and academic institutes.

Keywords— surface water quality, sustainable water management and Samut Songkram**.**

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I. Introduction

SAMUT Songkram province is a small province, located at central of Thailand near the mouth of Mae Klong River. With regard to provincial strategic development, this province has been dedicated to ecotourism and hospitality. Currently in many areas, massive landscape has been changed from residential area to ecotourism purpose, especially area close to Mae Klong River and canal branches. Increasing a number of home stays, floating market and fireflies watching in many areas have directly impacts on local livelihood. The plan also promoted public participation strategy in configuring suitable service standard and carrying capacity with the balancing purpose between the use of natural resources and tourism activity**.**

As a result of SWOT analysis, the strengths of the province include magnificent natural resources and environment, diversity of careers, stock for marine and agricultural products, high quality of human resources and local lifestyle conservation. The weaknesses include degradation of natural resources and environment, threat of water pollution from neighborhood and improper water resources management [3].

In addition, ecotourism has been identified as having a potential in provincial development strategy because it comprises of many canals which are suitable for ecotourism activities. Besides, Mae Klong River was categorized into level three standard by Pollution Control Department, Ministry of Natural Resources and Environment [2]. It serves as one of the major rivers that obtain water from various sources and are suitable for agriculture, household consumption but need to be sterilized for quality improvement. In 2009, monitoring result shown that the degradation of water resource nearby police station in Amphawa area is very high and only useful for transportation purpose due to the release of wastewater from surrounding tributary canals.

In 2010, Department of Environmental Science, Suan Sunandha Rajabhat University has conducted environmental research in Amphawa area, Samut Songkram Province as

ISBN: 978-1-61804-239-2

identified by university strategic plan and found that water quality in Amphawa canal is still supplies of good water quality except some parameters such as nitrate, ammonia and lead quantity that are higher than standard [1]. Regarding to Tha Ka, Bangkae and Kwae Om canals, only cadmium and lead quantities are higher than surface water quality standard [4]. The reasons behind the degradation come from the discharge of wastewater from nearby upstream provinces, lack of potable water sources and lack of quality analysis for domestic consumption. Some communities might be at risk because they brought water from canals and underground water sources directly without monitoring the impact of water on their health.

As a consequence, this research aimed to study water quality in Samut Songkram Province by investigating raw water for household consumption and also study the relationship between water quality and seasonal variability. Geographic information system has been used as a tool to handle and to analyze water resources data in order to propose sustainable water resources management in Samut Songkram Province..

II. Materials and Methods

A. Study Area

Surface water were collected and analyzed in three areas of Samut Songkram Province namely; Muang, Amphawa and Bang Khon Thee Districts as shown in Figure1.

1) Muang area has 69 sampling sites (7 from three canals, 1 from river and 61 from small tributary canals)
2) Amphawa area has 72 sampling sites (9 from canals, 2 from river and 61 from small tributary canals)
3) Bang Khon Thee area has 68 sampling sites (6 from canals, 3 from river and 59 from small tributary canals)

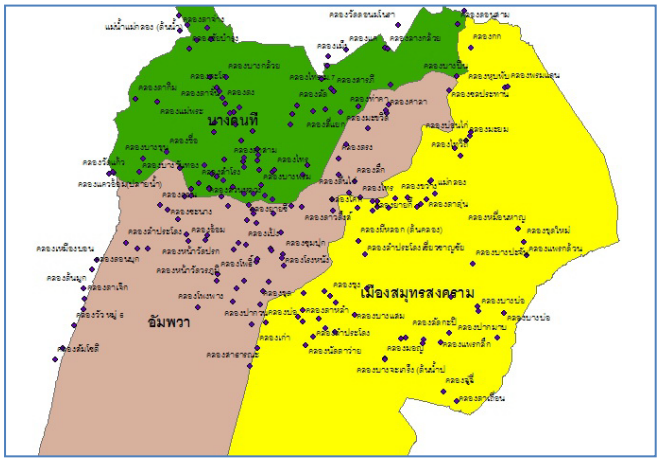

Figure. 1 Sampling sites in Samut Songkram Province

B. Research equipments

1) Water sampling and water depth meter
2) Sampling and preservation container
3) pH meters “HANNA HI 98217 and HORIBA D-54 models
4) Turbidity meter Lovibond TurbiCheck
5) Dissolved oxygen meter HORIBA OM-51
6) Salinity meter
7) Global positioning system GARMIN Etrex 20
8) Atomic absorption spectrophotometer GBC Avanta ver 2.02
9) Spectrophotometer
10) Ammonia distillation apparatus
11) BOD incubator
12) Cadmium column
13) Weight balance
14) Humidity incubator
15) Thermometer
16) Laboratory glassware
17) Chemicals for analyzing water quality

C. Methodology

A survey research has been conducted in Samut Songkram Province as the following:

1) Survey and study water quality for household consumption in canals by sampling seasons (three seasons)
2) Analyze water quality by using methods and parameters as shown in Table 1
3) Statistical analysis of variance to water quality by using T-test

TABLE I

PARAMETERS AND METHODS USED IN WATER QUALITY ANALYSIS

No.	Parameters	Method of analysis	Place of analysis	
			Field	Laboratory
1	Turbidity	Turbidity meter	√	√
2	Total dissolved solids	Filtration paper		
3	Salinity	Salinity meter	√	
4	pH	pH meter	√	
5	Nitrogen in Nitrite form	Colorimetric method		√
6	Nitrogen in Nitrate form	Cadmium reduction method		√
7	Nitrogen in Ammonia form	Distillation Titrate method		√
8	Sulfate	Iodometric method		√
9	Chloride	DPD Colorimetric method		√
10	Hardness	Titrate with EDTA		√
11	Dissolved	Azide modification or	√	
12	Oxygen BOD	DO meter Azide modification or		√
13		DO meter at 20 degree		√
14	Lead	celcius for 5 days		√
15	Cadmium	Atomic absorption-		√
	Fecal Coliform	Direct aspiration Atomic absorption- Direct aspiration Multiple tube fermentation technique		

III. Results and Discussion

A. Surface water quality

Surface water quality was measured from 217 sampling sites from 3 seasons as shown in Table 2. Prominent results can be concluded as the following;

Range of water temperature from canals in Amphawa, Bang Khon Thee and Muang Districts are 21.9-39.0°C (average 30.0°C), 25.0- 52.0°C (average 30.0°C) and 21.9-39.0°C (average 32.6 °C), respectively. All values meet the surface water quality standard type III of PCD.

Range of pH for canal water in Amphawa, Bang Khon Thee and Muang Districts are 6.1-8.8 (average 7.9), 6.8-8.6 (average 7.69) and 5.4-8.7 (average 7.45), respectively. All of pH values are also meet the standard of surface water quality type III mentioned by PCD that a range of pH should be 5-9.

Total dissolved solids (TDS) values in Amphawa, Bang Khon Thee and Muang Districts are 16-54,082 mg/l (average 528 mg/l), 58-400,180 mg/l (average 4,435 mg/l) and 31-29,200 mg/l (average 3,762 mg/l), respectively. However, TDS values cannot be compared with PCD standard because TDS did not appear in type III standard of surface water quality. From this study, tributaries canals in Bang Khon Thee District have the highest TDS values.

TABLE II

Surface water quality in Samut Songkram Province

Parameters	Values	Location			Seasons		
		Muang	Amphawa	Bang Khon Thee	Winter	Summer	Rainy
Temperature (°C)	Range	27.0-42.0	21.9-39.0	25.0-52.0	24.0-37.0	28.0-52.0	21.9-34.0
	Average	32.6	30.0	30.6	30.1	34.2	29.0
TDS (mg/l)	Range	31-29,200	16-54,082	58-400,180	16-400,180	52-57,186	31-29,200
	Average	3762	529	4,435	3285	3580	1934
pH	Range	5.4-8.7	6.1-8.8	6.8-8.6	5.4-8.8	6.1-8.7	6.5-8.3
	Average	7.4	7.6	7.7	7.7	7.6	7.4
DO (mg/l)	Range	1.15 - 7.47	0.76 – 8.90	0.62 – 9.50	0.62-9.50	1.17 - 8.9	0.76-8.8
	Average	3.20	4.27	4.63	4.16	3.91	4.04
BOD(mg/l)	Range	1.1-7.5	0.0-7.6	0-8.7	0-6.7	0.1-8.7	0-7.5
	Average	3.2	2.2	2.0	1.9	3.4	2.1
Turbidity (NTU)	Range	2.07-93.70	2.19-65.20	0.91-78.70	3.69-196.0	0.91-93.70	2.07-78.7
	Average	27.72	15.46	16.04	19.43	24.57	17.61
Nitrate ($_{\mu}$g/l)	Range	0.00 – 668.00	0.00 – 256.36	0.00 – 848.36	0.00 – 9.14	0.00 - 133.55	0.05 – 848.36
	Average	30.79	9.38	40.03	0.31	11.33	65.86
Pb (mg/l)	Range	0.118 – 4.168	0.026 – 3.916	0.038 – 5.223	0.232 – 5.223	2.259 – 4.168	0.026 – 0.603
	Average	2.157	1.220	1.685	1.663	3.155	0.228
Cd (mg/l)	Range	0.000 – 5.545	0.000-3.526	0.004 – 5.244	0.471 – 2.792	0.000 – 5.244	0.004 – 0.062
	Average	1.743	0.026	2.007	1.206	3.969	0.020

A range of turbidity values from canal water in Amphawa, Bang Khon Thee and Muang Districts are 2.19-65.2 NTU (average 15.46 NTU), 0.91 – 78.70 NTU (average 16.04 NTU) and 2.07 – 93.70 NTU (average 27.72 NTU), respectively. However, there is currently no surface water quality standard for turbidity.

Dissolved oxygen (DO) content from canal water in Amphawa, Bang Khon Thee and Muang Districts are 0.76-0.89 mg/l (average 4.27 mg/l), 0.62-9.5 mg/l (average 4.63 mg/l) and 1.15-7.47 mg/l (average 3.20mg/l), respectively. Seasonal comparison has also been measured and found that DO contents are 0.62 – 9.50 mg/l (average 4.16 mg/l) in winter, 1.17-8.9 mg/l (average 3.91mg/l) in summer and 0.76-8.8 mg/l (average 4.04 mg/l) in rainy season. Refer to the level of dissolved oxygen in all areas, it is compliance with specific standard that DO content should not below 4 mg/l.

Range of Biochemical oxygen demand (BOD) from canals in Amphawa, Bang Khon Thee and Muang Districts are 0.0-7.6 mg/l (average 2.2 mg/l), 0.0-8.7 mg/l (average 2.0 mg/l) and 1.15-7.47 mg/l (average 3.20mg/l), respectively. Refer to surface water quality standard type three, Amphawa and Bang Khon Thee Districtsis compliance with. While, BOD content in Muang area is higher than the standard, but still more within type four standard (less than 4 mg/l).

Nitrogen content in nitrate form for Amphawa, Bang Khon Thee and Muang Districts are 0.0-256.36 µg/l (average 9.38µg/l), 0.00 – 848.36 µg/l (average 40.03µg/l) and 0.00 – 668.00 µg/l (average 30.79µg/l), respectively. Refer to surface water quality standard, all areas have nitrogen content below 5 µg/l and the quality in term of nitrogen content is acceptable.

Lead content in canal water for Amphawa, Bang Khon Thee and Muang Districts are 0.026-3.916 mg/l (average 1.220mg/l), 0.038 – 5.223 mg/l (average 1.658mg/l) and 0.118 – 4.168 mg/l (average 2.517mg/l), respectively. According to surface water quality standard, lead content in the water should not higher than 0.05 mg/l and therefore average water quality from all areas are over the standard (type III).

Cadmium content in canal water for Amphawa, Bang Khon Thee and Muang areas are 0.000 - 3.526 mg/l (average 0.260±0.685 mg/l), 0.004 – 5.224 mg/l (average 2.007 ± 2.002 mg/l) and 0.000 – 5.545 mg/l (average 1.743 ± 1.491 mg/l) respectively. In according to surface water quality standard, cadmium content in the water should not greater than 0.05 mg/l and therefore not acceptable based on type III standard.

When considering results of the studies, Lead content was found at range 0.026 to 5.223 mg/l with the average 1.69 mg/l. In comparison with the standard (less than 0.05 mg/l), lead content is therefore much higher than standard. Range of Cadmium content was found from 0-5.545 mg/l with the average 1.39mg/l. In comparison with the standard (less than 0.05 mg/l), cadmium content is therefore much higher than the standard. For the range of Iron content was found from 0-8.18 mg/l with the average 0.29mg/l, but no specific water quality standard for iron content.

Range of Zinc value was found from 0-6.941 mg/l with the average 3.55mg/l. In comparison with the standard (less than 1.00 mg/l), zinc content is therefore much higher than standard. Copper value was found from 0-6.91 mg/l with the

average 0.45mg/l. When compare with the standard (less than 0.1 mg/l), copper content is therefore slightly higher than standard.

The reason behind high concentration of heavy metals comes from pre-treatment process of samplings before sending to analysis. The samplings were first digested by conc. nitric acid before analyzing with Atomic Absorption Spectrophotometer (AAS). The measured metal concentrations are not only a content in the water, but also include metal content in dissolved sediments load.

Graph of major parameters of water quality in Samut Songkram also represented in Figure 2.

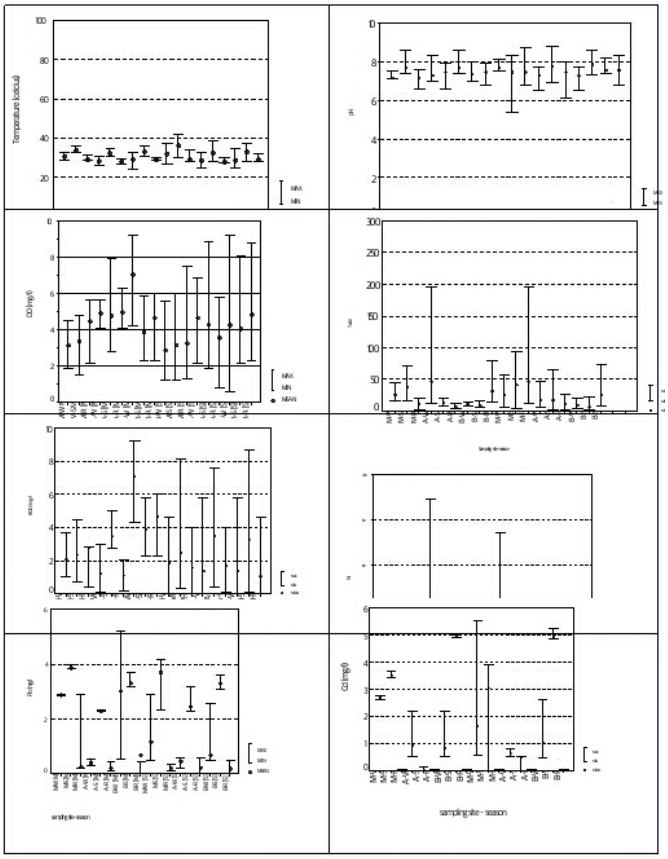

Figure. 2 Graphs illustrate average water quality of the prominent parameters in each season.

B. Analysis of seasonal variations of surface water quality

TABLE III

STATISTICAL ANALYSIS BETWEEN SEASONAL VARIATIONS AND SURFACE WATER QUALITY BY PAIRED – SAMPLES T-TEST

Parameters	Season	Statistical Significant		
		Winter	Summer	Rainy
Temperature (^{o}C) N = 198	winter	-	0.000	0.000
	summer	0.000	-	0.000
	rainy	0.000	0.000	-
pH N=200	winter	-	0.005	0.000
	summer	0.005	-	0.000
	rainy	0.000	0.000	-
TDS (mg/l) N = 196	winter	-	0.008	0.006
	summer	0.008	-	0.064
	rainy	0.006	0.064	-
Turbidity N=168	winter	-	0.072	0.010
	summer	0.072	-	0.000
	rainy	0.010	0.000	-
Nitrate N = 193	winter	-	0.000	0.000
	summer		-	0.000
	rainy	0.000	0.000	-
DO N = 204	winter	-	0.149	0.489
	summer	0.149	-	0.256
	rainy	0.489	0.149	-
BOD N= 201	winter	-	0.000	0.339
	summer	0.000	-	0.000
	rainy	0.339	0.000	-
Pb N= 42	winter	-	0.000	0.000
	summer	0.000	-	0.000
	rainy	0.000	0.000	-
Cd N = 86	winter	-	0.000	0.000
	summer	0.000	-	0.000
	rainy	0.000	0.000	-

Remarks: 0.05 level of significance

Paired sample T-test analysis have been conducted in order to find out the difference of water quality and seasonal variations. Results revealed that pH and temperature are different statistically significant at 0.05 level of significance.

Seasonal variations of Total dissolved solids (TDS) between winter and summer, winter and rainy have statistical difference ($\propto$ = 0.008 and $\propto$ = 0.006). However, no statistical difference between summer and rainy seasons ($\propto$ = 0.064)

Seasonal variations of Biochemical demand (BOD) between summer and rainy season have statistical difference ($\propto$ = 0.000 and $\propto$ = 0.000). However, no statistical difference between winter and rainy seasons ($\propto$ = 0.339) Seasonal variations of nitrogen in nitrate form, lead, and cadmium have statistical difference as well.

Whereas, no statistical difference between seasonal and dissolved oxygen

IV. CONCLUSION

From the investigation of surface water quality in Mae Klong River, main and tributaries canals which flow through three districts in Samut Songkram Province, were found that water quality meet the standard type III of surface water quality as issued by National Environmental Quality Act B.E. 1992. A framework of water quality management for domestic consumption in Sumut Sonkram Province is categorized by water quality and water utilization as the following;

A. Surface water quality management plan

The results of impurity in form of BOD and Nitrate which are represent as an indicator of organic content and nutrient for plant growth revealed that surface water quality in three districts of Samut Songkram Province consists of organic contaminations. A level of nutrient present in surface water needed by plant growth meet the standard type III of surface

water quality standard and is suitable in withdrawing for agricultural purposes.

Regarding to the effect of pollutants on water quality, streams quality was largely affected by local people who live at riverside, canal and tributary canal. Pollutants come from various sources such as homestays and resorts, restaurants, orchards, small business. Concentrations of heavy metals were higher than surface water quality standard. For example, Pb, Cd and Zn are major pollutants for consumption. Thus, it needs to be effectively purified before consumption.

When focusing on hydraulic factors like sediment flow also considerate, two provinces namely; Kanchanaburi and Rachaburi, located in upstream watershed, can largely contribute in discharging wastewater into Mae Klong River and directly pass to downstream before flowing to Gulf of Thailand. All stakeholders such as central and local government agencies, industries and local people should concern this issue and take effective attention in order to find out suitable framework, plan and management system.

The surface water management framework for sustainable utilization and consumption include wastewater reduction practice at upstream sources; establish local gathering team to handle wastewater before discharge to water bodies; take corporate social responsibility (CSR) paradigm into practice; set up water quality monitoring stations in each area. Finally, government should establish integrated water resource management plan by collaborating with local people both in short term and long term period.

ACKNOWLEDGMENT

This research was supported by National Research Council of Thailand and Suan Sunandha Rajabhat University. Special thanks also extended to the Samut Songkram Province Staff, and students of SSRU who helped and supported this project.

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