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TEMPORAL PATTERNS OF WATER QUALITY VARIATION IN KHLONG U-TAPAO RIVER BASIN, THAILAND

Saudee Maprasit[1], Chaisri Suksaroj[2] and Rotchanatch Darnsawasdi[3]

[1]Faculty of Environmental Management, Prince of Songkhla University, Thailand;
[2,3]Prince of Songkhla University, Thailand

ABSTRACT: Temporal patterns of water quality variation in Khlong U-Tapao river basin of Thailand were analyzed for 21stations along the river basin. This research objective is to study correlation of water quality by temporal variation of climatic-hydrology in years of 2007-2013. Using multivariate statistical analysis to analyze water quality of dataset 9 parameters such as pH, water temperature (WT), turbidity (TB), conductivity (CD), dissolved oxygen, (DO) biochemical oxygen demand (BOD), total coliform bacteria (TCB), fecal coliform bacteria (FCB) and Ammonia Nitrogen (NH_3-N). The results show that seasonal change has affected to water quality by variation of climatic-hydrologic parameters. The climatic-hydrologic water quality relationship is maximum climatic temperature had positive with WT but negative with NH_3-N. The temporal hydrologic-water quality relationship is precipitation had positive with TB but negative with WT, pH and DO. Water inflow had positive with TB but negative with WT and CD. Water outflow had positive with TB and DO but negative with WT. Water level had positive with TB, BOD and TCB. The spatial-temporal hydrologic-water quality relationship is river cross-section had positive with WT and CD but negative with DO. The assessment from multiple linear regression equations can explain water quality variations by climatic-hydrologic factors. Therefore, water quality management should be consideration climatic-hydrologic variation to provide basal information for developing improved water pollution control procedures of Khlong U-Tapao river basin.

Keywords: Water quality, Climatic-hydrologic factors, Multivariate analysis, Khlong U-Tapao river basin

1. INTRODUCTION

There are large scale and plenty of factors in water quality management, including population growth and density, land use in each pattern and practice of urbanization, agriculture, aquaculture and industry comprehensive all activity in water supply system [1]. The unpredictability in the water quality management is physical characteristics and phenomena change of nature. These are impact from geological attribute for example drainage pattern, land slope and soil property, hydrodynamic processes for example rainfall, runoff, river flow and discharge and climate for example temperature and solar radiation [2], [3].

The problem of water quality management in Thailand has uncertainty factors from natural change, for example in coastal zone of Phuket, wet season increasing water level and flow rate to making problem with wastewater discharge control from domestic and household. Geographic characteristics such as land slope and soils properties are aggravate to water quality degradation [4]. Rainfall, the cause of water level and water flow are higher than dry season to increase nutrients in river especially in agricultural zone of the Mun river basin [5]. Agricultural practice in Nakhon Nayok province in off-season is the problem for water quality management because of nutrients carried out to river by rain [6]. Wet season and rain fall make crisis with wastewater from industry and surface water in Lahan swamp of Chaiyaphum [7] and increasing nutrients in Ayutthaya watershed because of water level and water flow increased [8].

Accordingly, water quality study and management in Khlong U-Tapao river basin should be operation in system by consideration quantity of system components and interrelationship behavior with fluctuate and uncertainty variables. The relationship between climatic and hydrologic factors and all those variables have direct impact to water quality or not, because water quality management projects are determined and operated. Even if water quality continuing deterioration, therefore the management should be consideration in other factors such as climate and hydrology variations [9]. Seasonal change is temporal effected from climate and can affect to hydrological processes [10]. Which it can induce water quality variation by increased rainfall is the main driver for water level and water flow change [10].

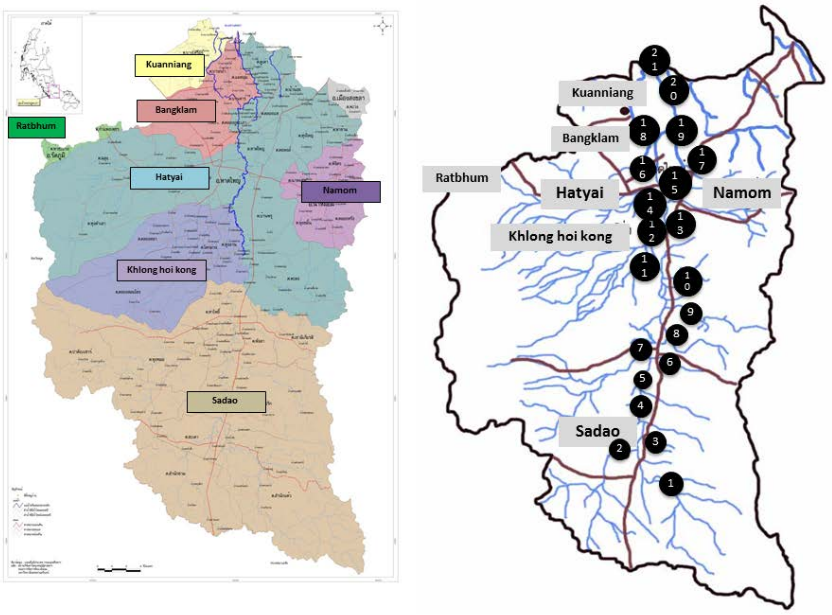

Fig. 1 Map of the Khlong U-Tapao river basin and water quality monitoring station

There are more researches to study impact from hydrology to water quality, from hydrology to water quality and from land use change to water quality. But there is incomplete understanding of the complex influence relationship among climatic variation in maximum and minimum value with spatial-temporal hydrology especially in Khlong U-Tapao river basin.

So, the conclusion of the study and implication for water quality management in Khlong U-Tapao river basin are complex system education and problem solving. The management should be administrative based on temporal-spatial change by considered human activity change and behavior of natural dynamic change including the assessment under different scenarios. This research objective is to study correlation of water quality by temporal change of climatic-hydrologic variations.

2. STUDY AREA

Khlong U-Tapao river basin (KUT) is a main Songkhla lake sub-basin which located at southern part of Thailand. There are about 40 km wide (west to east) and 60 km long (north to south). It is important water resource for people living in Songkhla province and Hatyai district which is economic significance [11], [12]. There are 2,840 square kilometer and 7 district (fig.1) such as Sadao, Namom, Hatyai, Khlong hoi kong, Bangklam, Ratpum and Kuanniang. Land use-land cover (LULC) in the area of Khlong U-Tapao can classify in 8 main groups [12]. There are residential land uses, agricultural land uses, forestry land uses, industrial land uses, shrimp farming, water resources both of natural and manmade, lowland and other land uses for example fields, waste landfills, recreation zone, golf court, airport, graveyard and others.

3. MATERIALS AND METHODS

3.1 Data

Data gathering: to collect secondary data for water quality such as, pH, water temperature (WT), turbidity (TB), dissolved-oxygen (DO), conductivity (CD), biochemical-oxygen-demand (BOD), Total-Coliform-Bacteria (TCB), Nitrogen-Ammonia (NH_3-N) and Fecal-Coliform-Bacteria (FCB) from Regional Environmental Office 16, Songkhla from 2007-2013. The secondary data of water quality come from 21 stations along the Khlong U-Tapo river basin (Fig.1, table 1) and cover 13 administrative districts, there are 4 sub-district administration organization (SAO), 6 sub-district municipality (SM) and 3 town municipalities (TM).

Climate variables; there are maximum, minimum and mean of temperature (MAXT, MINT and MEANT respectively), humidity (MAXH, MINH and MEANH respectively) and wind flow from Songkhla Meteorological department.

Hydrology; there are precipitation (PRECI), inflow (IF) and outflow (OF) from Regional Irrigation Office 16, Songkhla. In the space parameter, there are cross-section (C-SECT) is computed by river width (RW) and depth (RD) from data of REO 16.

Table 1 water quality stations monitoring in KUT river basin

station	Station name	Geographic co-system		Canal	Location area
		x	y		
UT01	The bridge of huiku temple	664730.0	729095.0	Sadao	Samnak Taeo SAO
UT02	Sadao water supply office	659083.0	733842.0	Sadao	
UT03	the bridge of mitrsampan community	655884.0	729678.0	Krob	
UT04	The bridge of Saenpong school	656722.0	733392.0	Krob	Sadao TM
UT05	The bridge of Ban Namhua	654394.0	733327.0	Laeh	
UT06	The back of Safe skin medical factory	658130.0	736990.0	Laeh	
UT07	The bridge of Ban Huatanon	658774.0	737533.0	U-tapao	
UT08	the bridge of Ban Takianpao	658731.0	741088.0	U-tapao	Prik SM
UT09	the bridge of Ban thapohoak	659883.0	749279.0	U-tapao	Tha Poh SAO
UT10	the bridge of Muangkong temple	659264.0	754133.0	U-tapao	Phang La SM
UT11	the bridge of Ban Prao	662071.0	757846.0	U-tapao	
UT12	the bridge of Siam fiber board factory	661236.0	759087.0	U-tapao	Phatong SM
UT13	the bridge of Ban Khlongpom	661418.0	760892.0	U-tapao	
UT14	the bridge of Khlong Phla-Kokphyom	661033.0	762692.0	U-tapao	Ban Phru TM
UT15	The bridge of Bangsala temple	659416.0	766076.0	U-tapao	
UT16	the bridge of Hatyai university	661984.0	771489.0	U-tapao	Khohong SM
UT17	Water gate of Khlong U-tapao	661851.0	772341.0	U-tapao	Khuan Lang SM
UT18	the bridge of thasae temple	660804.0	777315.0	U-tapao	Khlong Hae TM
UT19	the bridge of Narungnok temple	662471.0	781796.0	U-tapao	Mae Tom SAO
UT20	the bridge of Kutao temple	662140.0	785665.0	U-tapao	Ku Tao SM
UT21	the bridge of Songkhla lagoon	661073.0	787729.0	U-tapao	

Note: SAO: Subdistrict Administration Organization, SM: Subdistrict Municipality, TM: Town Municipality (Department of Provincial Administration, Ministry of Interior, 2013).

3.2 Statistical analysis

A parametric study is a study process about parametric statistics for a normal distribution statistical data. There are several statistical procedures in this study such as two-sample t-test for compare the different of average value between two groups variable of dependent and independent, one-way-ANOVA is relationship test for more than 2 groups of in/dependent variables. Correlation and regression analysis is for related variables and water quality variation equations to explain trends of dependent variable by multiple independents [13], [14].

4. RESULT AND DISCUSSION

4.1 Relationship analysis of water quality variation by seasonal patterns

Results in table 2 and Fig. 2 reveal the significance correlations of water quality variation by temporal change of times and season. The correlation results show water quality change depends on temporal patterns such as time-period and season [15], [16]. In case of TCB and FCB are not changed by time because average value in each year not different (higher than standard value but increased a few in every year). CD is not depends on season that mean soluble matters is not different by seasonal change. pH, DO, BOD, NH_3-N, WT, TB, TCB and FCB were depends on seasonal change. Water quality in duration of rain season was significantly variation more than dry season. This could be explained by hydrologic variations.

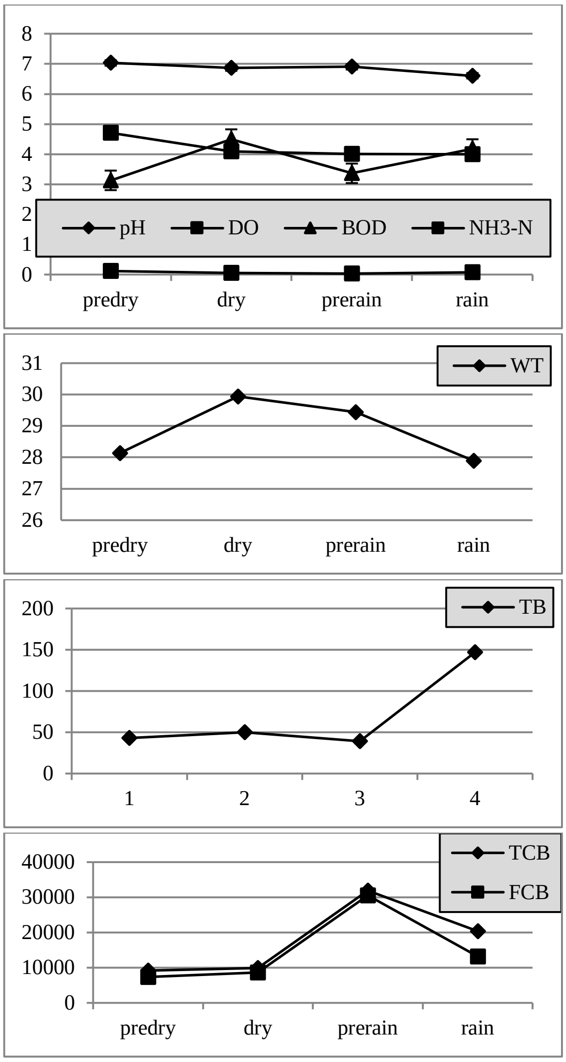

Fig. 2 water quality variation by seasonal change

4.2 Relationship analysis of climatic-climate and climatic-hydrology

From table 3-4, the result shows that, climate temperature in KUT river basin is affected by humidity and wind change. Almost climate temperature had positive correlation with humidity but negative with wind flow because wind flow can reduce temperature by dispersed but humidity can increase temperature by expanded heat energy. Climate MAXT had negative correlation with PRECI, W-level, Inflow, and river depth so MINT had positive correlation [17], [10]. All humidity change had positive correlation with hydrological variables. The phenomenon of precipitation into rainfall have affected by maximum climate temperature, the higher change can reduce occurred raining but higher humidity especially minimum value can support precipitation and hydrological parameters such as rainfall, water level and water flow.

4.3 Relationship analysis of hydrologic variation

Table 5, displays hydrodynamics from hydrologic change by water level, inflow, outflow and river depth had positive correlation with precipitation. According to hydrological cycle, an increased precipitation, it results in collection of rainfall in rivers. Therefore, water flow and discharge would increase by high water level. Water level had positive correlation with river width. A wide river would take more direct precipitation than narrow stream [10].

Table 2 Significant t-test/ F-test of temporal water quality

Parameters	WT	pH	TB	CD	DO	BOD	TCB	FCB	NH_3-N
Time (year)	0.000 **	0.000 **	0.000 **	0.025 **	0.002 **	0.000 **	0.886	0.715	0.000 **
Season (SS)	0.000 **	0.000 **	0.000 **	0.095	0.000 **	0.002 **	0.019 **	0.035 **	0.000 **

Note: **Significant at 0.01 level (2-tailed) / * Significant at 0.05 level (2-tailed)

Table 3 correlation analysis of Climatic variation

Parameters		Climate					
		MAXT	MINT	MEANT	MAXH	MINH	MEANH
Climate	MAXT	-	-	-	-	-	-
	MINT	0.541**	-	-	-	-	-
	MEANT	0.926**	0.695**	-	-	-	-
	MAXH	0.506**	0.653**	0.743**	-	-	-
	MINH	-0.101*	0.506**	0.256**	0.634**	-	-
	MEANH	-	0.534**	0.356**	0.746**	0.951**	-
	Wind	-	-0.337**	-0.169**	-	-0.350**	-0.275**

Note: **Significant at 0.01 level (2-tailed) / * Significant at 0.05 level (2-tailed)

Table 4 correlation analysis of Climatic-hydrology variation

Parameters		Climate					
		MAXT	MINT	MEANT	MAXH	MINH	MEANH
Hydrology	PRECI	-0.244**	0.231**	-	0.383**	0.699**	0.660**
	W-level	-0.109*	-	-	-	0.154**	0.138**
	Inflow	-0.250**	0.141**	-	0.187**	0.427**	0.391**
	Outflow	-	-	-	-	0.116*	-
	Width	-	-	-	-	-	-
	Depth	-0.177**	-	-	0.118*	0.259**	0.221**

Table 5 correlation analysis of hydrologic variation

Parameters		Hydrology					
		PRECI	W-level	Inflow	Outflow	Width	Depth
Hydrology	PRECI	-	-	-	-	-	-
	W-level	0.213**	-	-	-	-	-
	Inflow	0.610**	0.440**	-	-	-	-
	Outflow	0.292**	0.497**	0.627**	-	-	-
	Width	-	0.133*	-	-0.176**	-	-
	Depth	0.154**	-	-	-	0.280**	-

Note: **Significant at 0.01 level (2-tailed) / * Significant at 0.05 level (2-tailed)

Table 6 correlation analysis of Climatic-hydrologic water quality

Parameters		Water quality								
		WT	pH	TB	CD	DO	BOD	TCB	FCB	NH_3-N
Climate	MAXT	0.582**	0.249**	-	0.206**		-	-	-	-0.540**
	MINT	0.196**	0.220**	0.255**	-	-0.106*	-	-	-	-0.494**
	MEANT	0.507**	0.154**	-	0.163**		-	-	-	-0.558**
	MAXH	0.107*	-0.107*	0.288**	-	-0.236**	-	-	-	-0.505**
	MINH	-0.209**	-0.274**	0.574**	-0.121*	-0.209**	-	-	-	-0.208**
	MEANH	-0.114*	-0.266**	0.497**	-0.096*	-0.244**	-	-	-	-0.346**
Hydrology	PRECI	-0.145**	-0.328**	0.591**	-	-0.098*	-	-	-	-
	Inflow	-0.248**	-	0.434**	-0.144*	0.131*	-	-	-	0.188*
	Outflow	-0.167**	-	0.301**	-	0.278**	-	-	-	-
	Width	0.350**	0.184**	-	0.211**	-	-	-	-	-
	Depth	-	-	0.558**	-	-0.194**	0.150**	0.273*	0.277*	-

Note: **Significant at 0.01 level (2-tailed) / * Significant at 0.05 level (2-tailed)

4.4 Relationship analysis of climatic-hydrologic water quality

Results of significance correlation of climate change, hydrological processes and water quality of KUT river basin in table 6, explain the impact of water quality change based on climatic-hydrologic change by follows;

Climate temperature had positive correlation with WT, pH, TB and CD but negative correlation with DO and NH_3-N. It is possibly explained, water temperature is directly impacted by climate temperature (MAXT) [10], [2] and increased pH is comes from increased chemical change form high climate temperature and induce to alkalinity in water. So, dissolved oxygen and nutrients is reduced from biological and chemical process [19], [10].

Climate humidity had negative correlation with WT, pH, CD, DO and NH_3-N but positive correlation with TB. Humidity can expand climate temperature, therefore water temperature is decreased can induce to decline the biological-chemical process [18], [10] and for turbidity may come from the after-effect from water flushed on surface soils [10], [20].

Hydrological process is showed by precipitation (PRECI) had negative correlation with WT, pH and DO but positive with TB. Results mean water temperature is affected by precipitation. Which lower temperature is leading pH and DO decreased by TB increase can reduce absorbed DO and biological-chemical process [10], [18].

Water flow (inflow and outflow from reservoirs) had positive correlation with TB, DO and NH_3-N and negative with TEMP and CD.

Table 7 multiple linear regression equations

Parameter	Multiple linear regression equations	R	R^2	Sig	Multi-collinearity
WT	8.754- 0.209(DO) +0.625(MAXT) -0.018(OF) +0.026(RW)	0.757	0.573	**	0.70-0.99
pH	5.304+ 0.009(RW) -0.056(WT) +0.136(MINT) -0.002(PRECI)	0.424	0.180	**	
TB	86.794 +38.826(RD) -3.716(WT) +5.164(OF)	0.797	0.635	**	
CD	-408.04 -0.764(RW) +67.736(pH) -1.756(IF) +2.187(MAXT) +1.244(DO)	0.380	0.144	**	
DO	13.131- 0.083(RD) -0.258(WT) -0.136(BOD) -1.227(Wind) +0.002(PRECI) +0.064(OF) +0.034(MAXH) -0.018(IF) -0.098(MINT)	0.739	0.545	**	
BOD	4.431 -1.124(DO) +0.126(MAXT) -0.022(RW) +0.411(RD)	0.459	0.211	**	
TCB	6984.179 -3030.444(RD) -345.027(SS) +85.830(TB) -835.662(DO) +1.002(FCB)	0.988	0.976	**	
NH_3-N	1.498 -0.001(TB) +0.004(BOD) -0.042(MAXT)	0.603	0.364	**	

Note: **Significant at 0.01 level

Water flow (inflow and outflow from reservoirs) had positive correlation with TB, DO and NH_3-N and negative with TEMP and CD. Water flow is a driver for turbidity increase [20] and soluble matter decrease. The increase of water flow can flushed erosive soils and nutrients from land surface and increase sediments in river [10], [19], [21] but in other words it can decrease conductivity by carried soluble matters along the river that not similar to the study of [10], [18] but similar with the study of [19].

River cross-section in terms of river width had positive correlation with WT, pH and CD and depth had positive correlation with TB, BOD, TCB and FCB but negative with DO. The river width can increase water temperature and leading to rising pH and conductivity by increased chemical change. The river depth is depends on water level, therefore turbidity and waste-matter is increased by flushed water [10], [20], [21] and large amount at river bottom.

4.5 Multiple linear regression analysis

Water quality variation is impacted by climatic-hydrologic variation can explained by regression equations from table 7 and Fig. 3;

Water temperature (WT) variation is depend on MAXT, DO, OF and RW with moderate coefficient of determination values (R^2). Maximum climate temperature is a main driver to increase water temperature. Increased river width can directly high accumulation of solar heat and induce high water temperature. Reservoir outflow water can reduce temperature by rising DO and heat ventilation [16].

Turbidity (TB) variation refers to total suspended solids can explained by climatic-hydrologic change. River depth and outflow are major factors to impact on turbidity with moderate coefficient of determination values (R^2). A rainy season was significantly with increased turbidity because of frequency heavy rainfall, which cause the infiltration of sediments into stream by discharge flow and erosive surface soils [10], [16], [19].

Dissolved Oxygen (DO) variation is impacted by climate variables such as wind flow, MINT, MAXH and hydrology by PRECI, water flow and river depth with moderate coefficient of determination values (R^2). Increased climatic temperature causes a decrease in oxygen solubility [16]. Increased inflow water was indicating the possible organic solids transported from surface soils to surface stream and causes reduce oxygen by aerobic microorganisms using for biodegradable processes [10].

Total coliform-bacteria (TCB) were affected by river depth, the driving source of this parameter with high coefficient of determination values (R^2). TCB and FCB were higher during the end of dry season. This result shows that water flow in rainy season was the major of bacteria transportation from river to another source and was not similar result to [22].

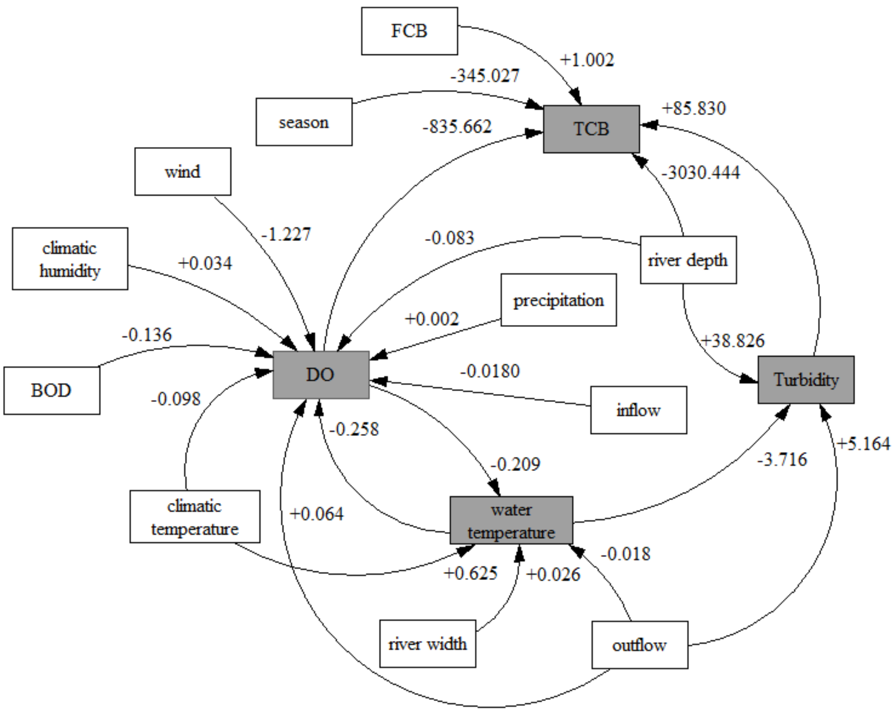

Fig. 3 Relational diagram

The variations of pH, Conductivity (CD), BOD and NH_3-N is a few explanation by climatic and hydrology with multi-collinearity conditions. This suggests that other factors should be consideration in the regression equations to explain the variation of water quality with good coefficient of determination values (R^2).

5. CONCLUSION

The temporal pattern of water quality variation in Khlong U-Tapao river basin depends on temporal parameters such as climatic- and hydrologic variations. Water quality was trend by seasonal change. Seasonal climatic-hydrologic factors were significantly correlations with water quality. Climatic temperature, precipitation, water level, water flow and cross-section are main drivers to impact water quality. Water temperature and NH_3-N are as sensitive for monitoring impact from climatic variation and turbidity as for hydrologic variation.

The multiple linear regression equations of water temperature, turbidity dissolved oxygen and total coliform-bacteria were indicate that can be used to explanation water quality trends by climatic-hydrologic variation. Accordingly, regression equations could to be develop for water quality modeling but more extensive study is needed to determine the effect of land use change.

In conclusion, temporal patterns of water quality variation may can help define guidelines for water quality management planning, should be consideration climatic-hydrologic change for developing improved in protection and control wastewater discharge from various land use based on temporal climatic-hydrologic change.

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7. REFERENCES

[1] UNICEF/WHO, "UNICEF Handbook on Water Quality", New York, 2008, pp. 1-2.

[2] Rehana S and Mujumdar PP, "River water quality response under hypothetical climate change scenarios in Tunga-Bhadra river,India", Hydrological Process, Vol. 25 (23), 2011, pp. 3373-3386.

[3] Tsakiris G and Alexakis D, "Water quality models: An overview", European Water 37, 2012, pp. 33-46.

[4] Pasinee R, Carter RW, Suchai W and Crossland CJ, "Wastewater discharge degrades coastal waters and reef communities in southern Thailand", Marine Environmental Research Vol.69, 2010, pp. 287-296.

[5] Akter A and Babel MS, "Hydrology modeling of the Mun River basin in Thailand", J. of Hydrology Vol.452, 2012, pp. 232-246.

[6] Seeboonruang U, "A statistic assessment of the impact of land uses on surface water quality indexs", J. of Environmental Management Vol.101, 2012, pp. 134-142.

[7] Pongpetch N and Suwanwaree P, "Spatial Water Quality Assessment and Mapping of Lahan Swamp, Chaiyaphum, Thailand", Procedia Environmental Science Vol.13, 2012, pp. 655-659.

[8] Supatimusro D, Areerachakul N and Poomsripanon J, "The Applied Geographic Information System and the Relation of Mollusk with Water quality in Ayutthaya Province, Thailand", Energy Procedia Vol. 34, 2013, pp. 99-108.

[9] Li YP and Huang GH, "Two-stage planning for sustainable water-quality management under uncertainty", J. of Environmental Management, Vol.8, 2009, pp. 2402–2413.

[10] Prathumratana L, Sthiannopkao S, Kim KW, "The relationship of climatic and hydrological parameters to surface water quality in the lower Mekong river", Environment International, Vol.34, 2008, pp. 860-866.

[11] Gyawali S, Techato K, Yuangyai C and Monprapussom S, "Assessment of Surface Water Quality Parameters and Their Variations for Effective River Monitoring System: A Case Study of U-Tapao River Basin", J. of Environ. Res. Vol.34 (2), 2012, pp. 89-106.

[12] Regional Environmental Office 16, Songkhla, "Water quality in Khlong U-Tapao river basin", year reports of 2006-2014.

[13] Ethington B., "THINGS TO KNOW ABOUT REGRESSION:, EDPR 7/8542, Spring, Retrieved on 07 June 2013 from https://umdrive.memphis.edu/yxu/public/Bunty's%20REGKNOW.pdf

[14] Patrasinee P, "chapter7: multiple linear regression analysis", Statistics for Scientific research, 1st ed. Bangkok: Chulalongkorn University, 2007, pp. 279-302.

[15] Karakoc G, Erkoc FU, Katircioglu H, "Water quality and impacts of pollution sources for Eymir and Mogsn lakes (Turkey)",

Environment International, Vol.29, 2003, pp. 21-27.
[16] Kannel PR, Lee S, Lee YS, "Assessment of spatial-temporal patterns of surface and ground water qualities and factors influencing management strategy of groundwater system in an urban river corridor of Nepal", J. of Environmental Management, Vol.86, 2008, pp. 595-604.
[17] McCarthy JJ, Canziani OF, Leary NA., "Climate change 2001; Impact, adaptation, and vulnerability", Cambridge University Press; 2001, pp. 195-233.
[18] Welsch DL, Cosby BJ, Hornberger GM, "Simulation of future stream alkalinity under changing deposition and climate scenarios", J. of Sci Total Environ, Vol.367, 2006, pp. 800–810.
[19] Zhao J, Fu G, Lei K, Li Y, "Multivariate analysis of surface water quality in the Three Georges area of China and implications for water management", J. of Environmental Sciences, Vol.23 (9), 2011, pp. 1460-1471.
[20] Chang H, "Spatial analysis of water quality trends in the Han river basin, South Korea", Water Research, Vol.42, 2008, pp. 3285-3304.
[21] Teeraphol S, Veerasak U. and Nuchanata M, "The specific hydro meteorological characteristics on soil loss and sediment transportation of the upper Lam Phra Ploeng watershed, Wang Nam Khieo subdistrict, Wang Nam Khieo district, Nakhon Ratchasima Province", in Proc.1st sustainable land use and natural resource management, Conf. on Bangkok, Thailand, 2004, pp. 33-42.
[22] Maillard P, Pinheiro Santos NA, "A spatial-statistical approach for modeling the effect of non-point source pollution on different water quality parameters in the Velhas river watershed-Brazil", J. of Environmental Management, Vol.86, 2008, pp. 158-170.

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Corresponding Author: Saudee Maprasit