SPATIAL VARIATIONS OF SURFACE WATER QUALITY AND POLLUTION SOURCES IN KHLONG U-TAPAO RIVER BASIN

Saudee Maprasit[1], Rotchanatch Darnsawasdi[1], Vichit Rangpan[2], and *Chaisri Suksaroj[3,4]

[1]Faculty of Environmental Management, Prince of Songkla University, Thailand;
[2]Faculty of Science, Technology and Agriculture, Yala Rajabhat University, Thailand;
[3]Faculty of Engineering, Prince of Songkla University, Thailand;
[4]Faculty of Engineering at Kamphaeng Saen, Kasetsart University, Kamphaeng Saen Campus, Thailand.

ABSTRACT: Multivariate statistical analysis, cluster analysis, parametric analysis, as well as factor analysis was applied to analyze water quality dataset including 9 parameters at 21 sites of the Khlong U-Tapao river basin in Songkhla province, Thailand, from 2007–2015 to investigate spatial variations of water quality and identify potential sources of pollution. Using cluster analysis to classify the three-periods of water quality variation in each monitoring site has shown 3 water quality measures: high, moderate and low. Using parametric study to describe variations of water quality and the significantly identified land use variables affecting water quality, such as urbanization and industrial land use which are sources of pollution in upstream. However, in midstream, Economical urbanization is the pollution source while agricultural land use is the pollution source in downstream. Factor analysis identified that the major pollutants in the upstream were turbidity and conductivity matter from soil erosion in the rainy season and industrial wastewater, in the midstream, the biochemical oxygen demand of organic matters from wastewater discharge from domestic settlements were the main pollutants while in downstream, nutrients from agricultural practices were the major pollutants. From upstream to downstream, bacterial pollutants were the main pollutants from all activities. These results provide fundamental information for developing better water pollution control strategies for the Khlong U-Tapao river basin.

Key words: Water quality; Spatial variations; Multivariate statistical analysis; Khlong U-Tapao river basin

1. INTRODUCTION

Water, the one-fourth natural resources to developing human life quality. The drive source of various systems, for example, the socio-politico-economical system of human activities. There are urbanization, agriculture, aquacultures, and industries. Water quality, the indicator was pointed suitability which relevant to characteristics of physical-chemical-biological properties for use in each activity of human life execution. A development is related to water quality degradation [1]. One of the Nations significance natural resource concern issue is water quality management [2]. The execution contains various components and uncertainty of qualitative and quantitative information from the interrelationship in their [3], [4]. The main component influence water quality to degradation is products from the point-nonpoint source of human life development, a pollution source to water quality. The various land use leachate is a major issue in study and management [2].

The obstacle of water quality management is large scale and plenty of factors, including population growth, land use in each pattern and practice of urbanization, agriculture, aquaculture, and industry comprehensive all activity in water supply system [5]. Therefore, to evaluate the state of water quality, the spatiotemporal influential factors such as season and land use change are considered to investigate the impact on water quality [6]. Seasonal change and urban land use change is the impacts on surface water quality, for example how urban scenarios encourages in low, normal and commercial urban growth impact on water quality [7]. Furthermore, water quality changes by seasonal change and nutrients loading from land degradation, sediment with nutrients from agricultural land use are damaging to catchment aquatic systems, almost of pollutants from a point source of industrial land use such as wastewater discharge. Population growth, unplanned domestic, deforestation, farming and livestock intension, agriculture expansion and infrastructure are a human activity which differently impacts on water quality.

Land use is the major source of pollution in river water basin. All relationship there is the question

what is the affection land use change to water quality, what is the season factors causing different land use and transformation and what is the consequence of the results to water quality. Land use type, occupation, and transformation causing to different hydrology and what is the water quality outcome. Therefore, the study in water quality management must know how the relationship of water quality by land use change with seasonal change.

Water quality studies and management in Khlong U-Tapao river basin for problem-solving are complex system education that focused on related factors based on temporal-spatial change. Study in water quality and management just to study behavior and trends of dynamic change include relationship and interaction of variables in the system under different of spatial and temporal including land use change and seasonal parameter. The objectives of this study are quantified the contributions impact of the spatial-temporal change to water quality and recognize water quality system. In addition to discussing and point pollution sources for how to solve the impact of land use practice and human-driven force on water quality and what feasible actions should be taken from causing adverse effects in each season.

2. STUDY AREA

Khlong U-tapao is a sub-basin of Songkhla lake basin located in southern part of Thailand. The basin is about 60 km long from north to south, and 40 km wide from west to east, and total coverage is about 2,805 square kilometers [8], [9], [10] (Fig.1). There is 7 districts such as Sadao, Namom, Hat Yai, Khlong Hoi Kong, Bangklam, Ratpum, and Kuanniang.

Pollution sources in Khlong U-Tapao river basin come from various land use which divided that, there are; 1) Residential Land Uses which are more found in the plain area or low land for example in Hat Yai municipality, Khohong sub-district municipality, Banpru municipality, Sadao municipality and comprehensive area of the sub-district administrative organization. 2) Agricultural Land Uses, for example, para-rubber plantation, paddy field, fruit plantation, palm plantation, farm of cows, buffalos and goats including shrimp farms. The area of paddy field is on the low land of the north or upstream of the basin, para-rubber and palm plantation is on the south or begin from midstream to downstream of the basin.
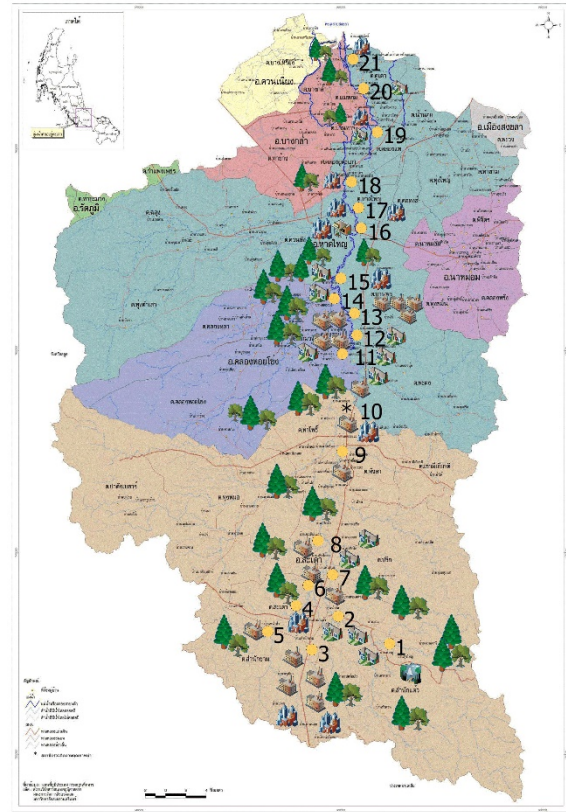

Fig.1 Khlong U-tapao river basin Map and land-use

Table 1 water quality monitoring sites

| station | Geographic Co-System | | Location area |
	Longitude (Easting)	Latitude (Northing)	
UT01	100.490	6.593	Samnak Taeo SAO
UT02	100.439	6.636	Sadao TM
UT03	100.410	6.599	
UT04	100.417	6.632	
UT05	100.396	6.632	
UT06	100.430	6.665	Prik SM
UT07	100.436	6.670	
UT08	100.436	6.702	
UT09	100.446	6.776	Tha Poh SAO
UT10	100.441	6.820	Phang La SM
UT11	100.466	6.853	Phatong SM
UT12	100.459	6.865	
UT13	100.460	6.881	Ban Phru TM
UT14	100.457	6.897	
UT15	100.442	6.928	
UT16	100.466	6.977	Khohong SM
UT17	100.465	6.984	Khuan Lang SM
UT18	100.455	7.029	Khlong Hae TM
UT19	100.471	7.070	Mae Tom SAO
UT20	100.468	7.105	Ku Tao SM
UT21	100.458	7.124	

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

Fruit plantation is distribution around of rural community area. 3) Forestry, which are an area of tropical rain forest, swamp forest, bother peat swamp and mangrove swamp and deciduous forest. Most of the tropical rainforest is found on the west of basin. 4) Industrial land use is a main of the various para-rubber process and frozen foods. All are found mostly in the urban community. 5) Water resources and 6) Lowland and bare land.

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) [10]. In this basin area was separated into 3 part such as upstream part, it started from station UT01 to UT09, midstream from UT10-UT17 and downstream from UT18-UT21.

3. MATERIALS AND METHODS

Water quality parameters was collected from secondary data of 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 2007-2015. Land use was separated into 3 types of agriculture, industry, and urbanization. Agricultural data was gathered from Provincial Agricultural Extension Office, Sadao district, Songkhla. Industrial data was gathered from Songkhla Provincial Industry Office. Urbanization was gathered from Department of Provincial Administration, Ministry of Interior,

A statistical analysis is used for a normal distribution. Correlation is studied for variable relationship by multiple independents [11], [12]. Cluster analysis is used to identify variations in water quality. Factor analysis is applied to use for identifying pollution factors which related to pollution sources of the river basin and performed this suitable method by Kaiser-Meyer-Olkin (KMO) and Barlett's test [13].

4. RESULT AND DISCUSSION

4.1 Water quality variations by seasonal change

The variations of water quality by seasonal change presented in fig.2 and table 2, in all the year, WT varied from 26.0-34.0 ^{0}C, pH from 4.4-9.2, TB from 3.0-307.48 NTU, CD from 0.01-15,064.0 µs/cm, DO from 0.10-7.60 mg/L, BOD from 0.40-

32.20 mg/L, TCB and FCB from 20.0- 1.60E+05 MPN/100mL and NH_3-N from 0.00-0.68 mg/L.

Table 2 water quality variations in dry and rainy season

Season / parameter		WT	pH	TB	CD	DO	BOD	TCB	FCB	NH₃-N
Dry	Min.	26.6	4.4	4.3	0.18	0.50	0.40	78.00	78.00	0.00
	Max.	34.0	9.2	110.0	15064.0	7.00	16.20	1.60E+05	1.6E+05	0.51
	Mean	30.0	6.9	50.8	357.26	4.01	4.33	1.19E+04	1.1E+04	0.07
	SD.	1.6	0.7	24.2	1667.67	1.40	3.40	2.73E+04	2.7E+04	0.11
Rain	Min.	26.0	4.6	3.0	0.01	0.10	0.50	20.00	20.00	0.00
	Max.	33.0	8.9	357.0	10680.0	7.60	32.20	1.60E+05	1.6E+05	0.68
	Mean	28.7	6.9	77.3	277.85	3.95	3.78	1.83E+04	1.8E+04	0.06
	SD.	1.3	0.9	76.9	987.07	1.36	3.03	4.01E+04	4.0E+04	0.11
All-year	Min.	26.0	4.4	3.0	0.01	0.10	0.40	20.00	20.00	0.00
	Max.	34.0	9.2	357.0	15064.0	7.60	32.20	1.60E+05	1.6E+05	0.68
	Mean	29.2	6.9	68.2	307.48	3.97	3.99	1.61E+04	1.6E+04	0.06
	SD.	1.5	0.9	65.0	1282.40	1.37	3.18	3.62E+04	3.6E+04	0.11

The result showed that WT, pH, DO and NH_3-N in the dry season was higher than rainy season. In another parameter, BOD, CD, TB, TCB, and FCB was higher during rainy than a dry season because of climatic and hydrologic change [8].
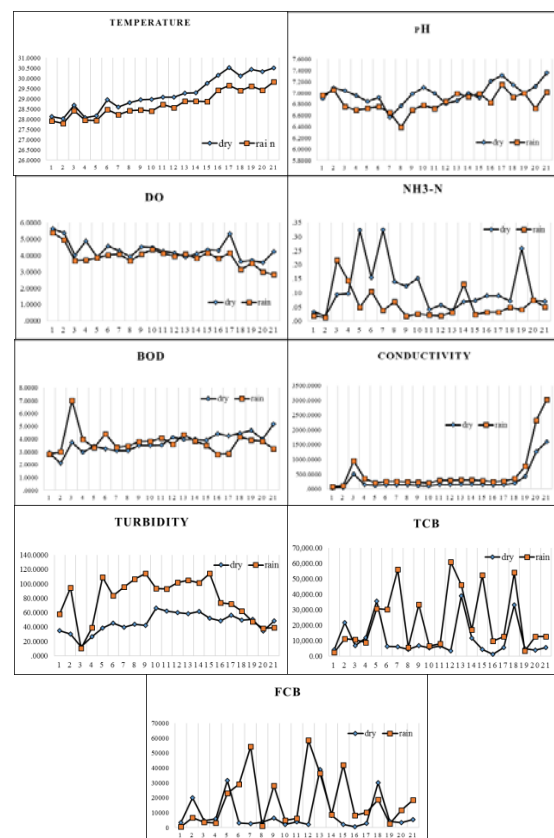

Fig. 2 water quality variations in dry and rainy season

4.2 Cluster analysis of water quality variations

Two-step Cluster analysis for continuous data was applied to classify the set of water quality variations into 3 variations periods follow by fig.3 and table 3, WT, CD, TCB, and FCB were classified into 2 periods but pH, BOD, DO, TB and NH$_3$-N were classified into 3 periods.

Table 3 Water quality period by cluster analysis

parameters	Water quality variations period		
	Period 1	Period 2	Period 3
	Low	Moderate	High
WT	-	29.78	28.49
pH	7.02	6.94	6.72
TB	77.10	69.25	30.26
CD	574.34	136.30	-
DO	3.89	4.00	4.80
BOD	4.82	3.85	3.03
TCB	27977	8497.5	-
FCB	17607.89	6790.73	-
NH$_3$-N	0.152	0.070	0.057

Water quality in period 1 presented low quality by the high value of pH, TB, CD, BOD, TCB, FCB, NH$_3$-N and low value of DO whereas high water quality was presented by the contrary.
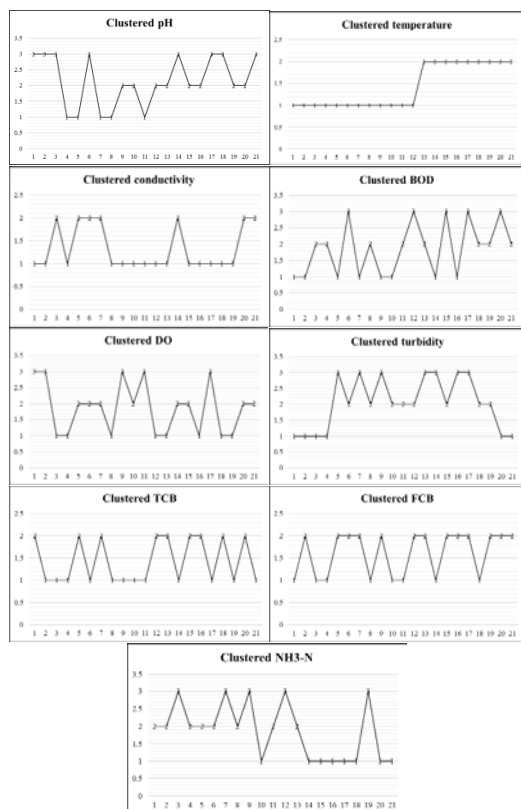

Fig. 3 water quality variations in dry and rainy season

Clustered water quality variations were presented in fig.3 and identified site station of pollution sources that upstream zone was site UT5 and UT7, midstream zone was site UT12, UT15 and downstream was UT19. Follow by table 4.

Table 4 pollution source in each zone.

Water quality	Site station of pollution sources in each basin zone		
	upstream	midstream	downstream
Low	5, 7	12,15	19
Moderate	3,6,9	13,16,17	18,20,21
High	8,4	14	-

4.3 Factor analysis of water quality variations

Factor analysis to identify group of water quality variation and the main pollution factors which showed results in table 5 and table 6;

Table 5 results of KMO and Bartlett's sphericity tests

Para-meter	Mean	SD.	Bartlett's Test of Sphericity		KMO
WT	29.23	1.48	Approx. Chi-Square	586.901	
pH	7.13	0.61			
TB	61.12	58.74			
CD	349.88	1017.75	df	36	
DO	4.45	1.42			0.516
BOD	3.38	2.54			
TCB	1.69E+04	3.57E+04			
FCB	1.34E+04	3.23E+04	Sig.	0.000	
NH$_3$-N	0.09	0.16			

In factor analysis, the KMO and Bartlett's sphericity test results are 0.516 and 586.901 (df=105, p<0.001), respectively, showing that this method was effective in reducing dimensionality [13].

Table 6 water quality factors on rotated component matrix during dry and rainy season

Variables	Non-rotated Component matrix				Rotated Component matrix			
	1	2	3	4	1	2	3	4
TCB	.944				.962			
FCB	.927			.242	.970			
WT		.738	.219			.729		
pH		.630		-.328		.707		
NH3-N			-.721	.373		-.569	.416	
DO	-.294	-.341	.589	.247			-.766	
BOD	.201	.274	-.485	-.310			.657	
CD		.406	.221	.543		.208	-.281	.646
TB	.358	-.460	.249	-.489				-.771
	Eigenvalue	1.961	1.417	1.342	1.217			
	% of variance	21.789	15.742	14.916	14.120			
	Cumulative %	21.789	37.530	52.446	66.566			

The first fourth rotated factors with an eigenvalue of 1 or greater are extracted using Varimax with Kaiser normalization, which can explain the total variance in water quality data set amount 66.565%.

Factor analysis identified 4 factors such as factor 1, which accounted for 21.8 % of the total variance, was a strong correlation with TCB and FCB. This factor could be interpreted as "bacterial pollutants" influenced by point sources such as urbanization with surrounding urban rim and human-made area such planted forest, agro-pastoral land and barren land [14]. Factor 2, which implied 15.7 % of the total variance with moderate correlation on WT and pH and primarily negative correlation on NH_3-N. Factor 2 suggests "nutrient pollution and transform", It presented natural factors impacted by seasonal change [8], [15]. The inverse relationship between temperature and nitrogen forms is a natural process of nitrogen cycle because warmer water is the cause of nitrogen transformation by the biological process [14]. Most of this pollutant could be caused by non-point sources such as agricultural runoff and or domestic sewage discharge directly into river basin without treatment [16].

Factor 3 explained 14.9% of the total variance and had a moderate correlation with BOD and strong negative loading on DO. This factor represented as "organic pollutants" which influenced by point source such as municipal and industrial effluents [16], [17] resulting from rapid urbanization as well as the economic area. The last factor, factor 4 accounted for 14.1% of the total variance and had a moderate correlation with CD and strong negative correlation on TB which represented "solids pollutants" and explained by influenced pollution originating from industrial sewage [16], [17].

4.4 Pollution source identification

In the upstream area, main pollution sources were from site monitoring UT05 and UT07 which factor 4 reflects the solids pollutants both of dissolved and non-dissolved solids. Almost turbidity in this area discharged during the rainy season which eroded soil from the land surface to the river. Electrical conductivity is high by industrial wastewater discharge from many para-rubber factories including rubber sheet, glove, and latex. In midstream area, main pollution sources were from UT12 and UT15 that factor 3 displays pollution of organic matter which almost discharges from large and economical urbanization. This zone is in Hat Yai district where a tourist attraction is. Some of

part are factories of palm-oil, animal-feed, and frozen food.

In downstream, main pollution source was UT19 which factor 2 represents pollution of nutrients in agriculture and aquaculture area. In this area are cover of small urbanization with paddy farm and agro-pastoral land. FCB and TCB are bacterial pollutions along the river basin. There is a problem in any parts of the river from upstream to downstream which influenced by wastewater discharge from domestic settlements. The management should be concentrate in a rainy season more than dry season. Spatio-temporal pollution sources can conclude in table 7. In the rainy season, upstream should consider site 5 and 7 areas, midstream should be concentrate site 12 and 15 areas and in the dry season, downstream should be intensified site 19 areas.

Table 7 Source and season identification of pollution

Basin zone	Site	factor	Season
upstream	UT05, 07	4	Rainy
Midstream	UT12, 15	3	Rainy
downstream	UT19	2	Dry

5. CONCLUSION

Water quality variations by spatial patterns could present various periods of water quality by multivariate statistical analysis, moreover, this method could explain a group of water quality variation in each part of land use. The upstream zone should be a consideration in the area of industry and urbanization, midstream zone should be concentrated in the area of economical urbanization and downstream zone should be managed in the area of agricultural land use as seasonal strategies. The rainy season, rainfall and level of water are the main cause of organic pollutants from land surface to river surface both of rural and urban area. Pollutants and waste controlling in these areas may be could reduce water quality degradation. For example, sufficiently construct wastewater treatment plant in urbanization, wastewater discharge controlling from industry and agricultural area restricting.

6. ACKNOWLEDGEMENTS

Songkhla, Songkhla Provincial Industry Office and Department of Provincial Administration, Ministry of Interior.

7. REFERENCES

[1] Praxeda KM, "Water quality management and sustainability: the experience of Lake Victoria Environmental Management Project (LVEMP), Tanzania", Physics and Chemistry of the Earth, Vol.28, 2003, pp. 1111–1115.

[2] United State Department of Agriculture (USDA), National water quality handbook, 2003, introduction.

[3] UNESCO/WHO/UNEP, "Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring" Second Edition. Published by E&FN Spon, an imprint of Chapman & Hall, 1992, 1996.

[4] 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.

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

[6] Kannel PR, Lee S, Lee YS, "Assessment of spatial-temporal patterns of surface and groundwater 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.

[7] Cyril O, Wilson and Qihao W, "Simulating the impacts of future land use and climate changes on surface water quality in the Des Plaines River watershed, Chicago Metropolitan Statistical area, Illinois", Science of the Total Environment, Vol.409, 2011, pp. 4387–4405.

[8] Maprasit S, Suksaroj C and Darnsawasdi R, "Temporal patterns of water quality variation in Khlong U-Tapao river basin, Thailand", Int. J. of GEOMATE, Vol.11, 2016, pp.2763-2770.

[9] 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.

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

[11] 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

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

[13] Vanichbuncha K, "Statistics for research. Faculty of commerce and accountancy. Chulalongkorn University, 2009, pp. 202-228.

[14] Maillard P and 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", Journal of Environmental Management, Vol.86, 2008, pp. 158-170.

[15] Singh K P, Malik A and Sinha S, "Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical technique: a case study", Analytica Chimica Acta, Vol.538, 2005, pp. 355-374.

[16] Mei K, Liao L, Zhu Y, Lu P, Wang Z, A.Dahlgren R, Zhang M, "Evaluation of spatial-temporal variations and trends in surface water quality across a rural-suburban-urban interface", Environ Sci Pollut Res. Vol.21, 2014, pp. 8036-8051.

[17] Zhao J, Fu G, Lei K and Li Y, "Multivariate analysis of surface water quality in the Three Georges area of China and implications for water management", Journal of Environmental Sciences, Vol.23(9), 2011, pp. 1460-1471.