Analysis of Changing Trend of Fecal Coliform Levels at Lakes in Hue Citadel, Vietnam

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ABSTRACT

To determine changing trends of fecal contamination at TinhTam, CayMung, TanMieu and HoVe lakes in Hue Citadel (Vietnam), this reseach sampled and monitored the fecal coliform level every two months from March 2013 to November 2014. There were a total of 11 samples collected at each site. Samples were determined by MPN method and based on standards of APHA. Mann-Kendall non-parametric test was used to analyze and assess changing trends based on Theil-Sen slope, using ProUCL 4.1 software. The monitoring results in the 21st month study period showed that the fecal coliform level at the lakes in Hue Citadel has large fluctuations in the rainy season (September and November). The result also indicated that TanMieu Lake has the highest level of fecal coliform. By statistical analysis and Mann-Kendall non-parametric test, the study indicated that there is an increase in the levels of fecal contamination at HoVe lake ($p < 0.05$), where the changing rate of the contamination at the value of 37.50 MPN/100 mL/month (450.00 MPN/100 mL/year) was also detected. The long-term solution is to prevent the discharge of the sources of fecal bacteria into the lakes in Hue Citadel.

Keywords: Lakes/ Change/ Fecal coliform/ Hue Citadel/ Mann-Kendall trend
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1. INTRODUCTION

Fecal coliform is thermotolerant and one of the groups within the total coliforms. It develops and ferments lactose at temperature 40-45 °C. Fecal coliform is often used as an indicator of warm-blooded animals and human fecal contamination in an environment. Fecal coliform is a source of fecal contamination of water. Direct contact with fecal coliform in contaminated water sources can have negative effects on community and environmental health. Warm-blooded animals and household waste is one sources of fecal coliform contamination. These contaminated sources can discharge into ponds, canals, rivers system, leading to contaminate additional water bodies. Especially for cycle lakes with poor quality, this increases the contamination concentration of fecal coliform.

The lakes system of Hue Citadel (Thua Thien Hue Province, Viennam) is known as cycle system including 41 different lakes (Tran and Vu, 1993). Water supply sources of these lakes are not only rainfall water but also untreated household wastewater. This urban source may have high fecal coliform levels. Lake water pollution is a great concern in developing countries. An important objective of environmental monitoring programs aims to determine polluted trend and assess of water quality. For monitoring of water quality, Taeng-On and Isara (2014) argued and assessed water quality status in correlation with the diversity of *Trichoptera* fauna. In a different study, Sateinpong et al. (2014) carried out the study of coastal water quality change aims to examination of water quality around the coastal zone. Previous research of lake systems in Hue Citadel focused on monitoring and assessing water quality based on Vietnam National Technical Regulation on surface water (QCVN 08:2008/BTNMT) (MONRE, 2008a) and lake eutrophic index (Le and Nguyen, 2013; Nguyen and Pham, 2012; Nguyen et al., 2012).

The lakes in Hue Citadel were selected for sampling and analysing water quality with parameters like temperature, pH, suspended solids (SS), electric conductivity (EC), dissolved oxygen (DO), chemical oxygen demand (COD), ammonia (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}), total nitrogen (TN), total phosphorus (TP), chlorophyll-a and total coliform, however it just carried out in during short-period from March to July in 2011. In this case, variations and trends of annual mean fecal coliform level time series were not examined. Those water quality assessments cannot present the trend of water quality, especially fecal contamination. The analysis of water quality trend has an important significance to compose water resources protection policies, healthy maintenance as well as lakes protection. Various pollution sources related to industrial, primarily agricultural and mining activities, are having a negative effects on ponds, rivers and streams. Sometimes, poor management by the local government may be the most significant source of fecal contamination rather than direct water pollution. It could be said that, the increasing urbanization and industrialization will have negative implications for water quality. Therefore, trend analysis of water quality fluctuations is essential for long term policy making. The trend analysis method was early proposed in 70s of last century, such as by Lettenmaier (1976) and Hirsch et al. (1982). In particular, a procedure related to a non-parametric correlation statistic between

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the water quality variables was suggested by Hirsch et al. (1982).

Recently, statistical techniques of trendy analysis to assess changes of water quality has been used by researchers such as Heejun (2008); Bouza - Deano et al. (2008); Chiueh et al. (2011); Faridah et al. (2012); Nguyen (2014); etc. Results from the study of Faridah et al. (2012) suggested the good management policy related to river quality in the Klang River (Malaysia). Meanwhile, Heejun (2008) carried out trend examine for eight parameters including temperature, pH, DO, BOD_5, COD, SS, TP, and TN. Similarly, the author Nguyen (2014) were sampled, analyzed and trendy tested water quality parameters including Temperature, DO, BOD_5, COD and TDS of Cu De River (Vietnam). Because of financial and time limits, the study could only conduct field surveys and establish monitoring stations to analyze, assess trends of fecal coliform levels at lakes in Hue Citadel.

The purpose of the study aims to applying Mann-Kendall non-parametric statistical technique to test fecal coliform trends at TinhTam, CayMung, TanMieu and HoVe lakes in Hue Citadel. This methodology will identify the water quality situation and support suitable information to control and mitigate the lakes' environmental pollution.

2. METRODOLOGY

2.1 Research area

Hue Citadel is located in the northern region of Perfume River in Hue City, Vietnam (Figure 1). With a total area of approximately 520 ha, Hue Citadel was built from 1803 to 1832 under the Nguyen Dynasty. Regarding climate character, Hue Citadel belongs to a tropical monsoon region with two distinct seasons. A dry season is hot and humid, usually starting from March to August; temperature can reach to 40 °C. The rainy season begins in late August, early September and ends in December. During rainy season, floods, heavy rains usually happen and the average temperature is approximately 20 °C. In the past, Hue Citadel has played an important strategic role, the administrative center of the Nguyen Dynasty. These days, Hue Citadel is still an active city with over 60,000 residents.

2.2. Methods

To conduct this study, authors conducted a field survey and establish monitoring stations to analyze, assess trends of fecal coliform parameters at lakes in Hue Citadel. Specifically, sampling sites of fecal coliform monitoring were selected at TinhTam, CayMung, TanMieu and HoVe lakes. Sampling frequency of the research was every two months from March (2013) to November (2014).

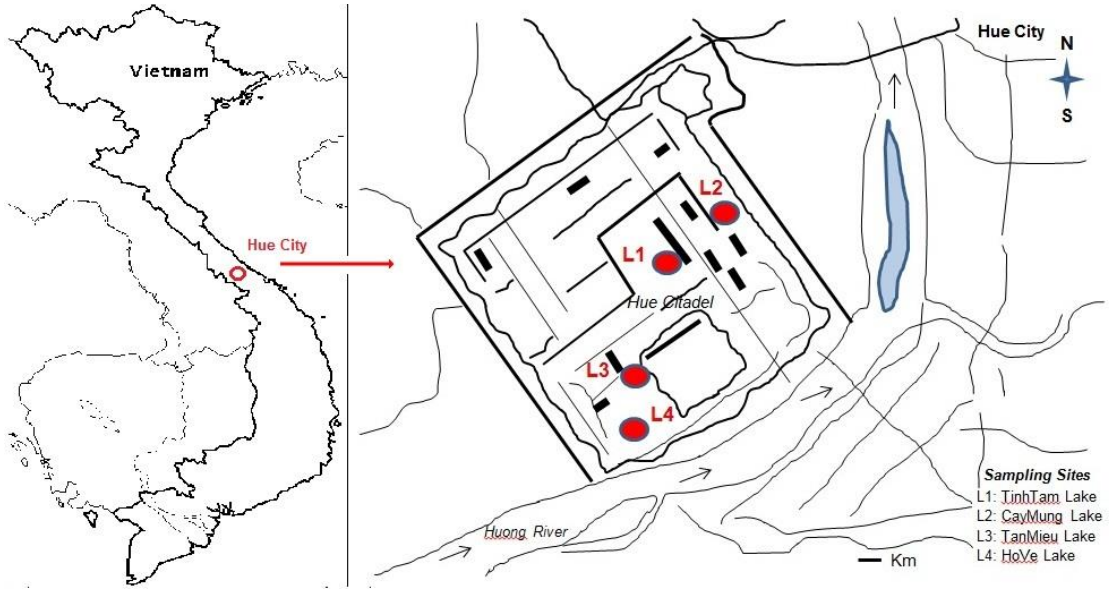

Figure 1. The study site in Hue Citadel

Sampling and analysis methods: Stations were identified using a Global Positioning System (GPS) unit. At each station, the total number of samples collected each sites were 11. Samples were taken at a depth of 10-30 cm below water surface at center of the lakes. The 44 total samples were collected during the period March 2013 to November 2014. All water samples were stored into sterile, polystyrene collection bottles. Samples were immediately placed in a cooler at 4 °C until fecal coliform analysis of samples were conducted. The sampling of research was pursuant to national standards TCVN 6663-1:2011 (MONRE, 2011) Water quality-sampling and APHA et al. (1999). Samples were stored and transported by national standards TCVN 6663-3:2008 (MONRE, 2008b). Fecal coliform levels were determined based on APHA standards. All results were reported as most probable number (MPN) of fecal coliform per 100 mL of water.

Fecal coliform trend test: The study used Mann-Kendall non-parametric test to analyze and evaluate

trends based on Theil-Sen slope (Kostas and Dimitra, 2012) by ProUCL 4.1 software. The Mann-Kendall is a non-parametric method to determine the trend of data by time. All hypothesis tests were performed at the 5% significance level. Considering the value chain x_1, x_2, x_3 … x_{n-1}, x_n performing n data points, where x_j is the data value at the time of j, the Mann-Kendall statistic index S is calculated by the formula (1):

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(x_j - x_i) \quad (1)$$

Where, n is the data points and sign(x) is defined as follows: sign(x) = 1 if x > 0; sign(x) = 0 if x = 0 and sign(x) = -1 if x < 0. The initial value of the Mann-Kendall statistic S is 0 and corresponds to non-existence of trend. The value S > 0 (positive) indicates an upward trend, the value S < 0 (negative) indicates a downward trend. However, it is required to calculate the probability associated with S and n to determine the significance of the trend. The variance statistic is given by formula (2):

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p-1)(2t_p+5)\right] \quad (2)$$

Where, g is the number of groups with the same data value, t_p is the number of data points in the first group p. The Z index is a standard normal distribution (mean 0, variance 1), the test statistics Z is calculated by formula (3):

$$\begin{cases} Z = \frac{S-1}{[VAR(S)]^{\frac{1}{2}}}, & S>0 \\ Z = 0, & S=0 \\ Z = \frac{S+1}{[VAR(S)]^{\frac{1}{2}}}, & S<0 \end{cases} \quad (3)$$

The tested results reject or fail to reject a null hypothesis a trend of increasing fecal coliform levels based on the value of the Mann-Kendall index Z. If Z > Zα/2: Reject H_0 hypothesis, i.e., the trendy existence; conversely, if Z < Zα/2: Fail to reject hypothesis H_0 (non-existence of trend).

3. RESULTS AND DISCUSSION

3.1 Results of fecal coliform monitoring in lakes of Hue Citadel

A mean value for each of fecal coliform results was calculated for each lake. The monitoring results during 2013-2014 showed a large variation of fecal coliform levels in the rainy season at lakes in Hue Citadel (Figure 2).

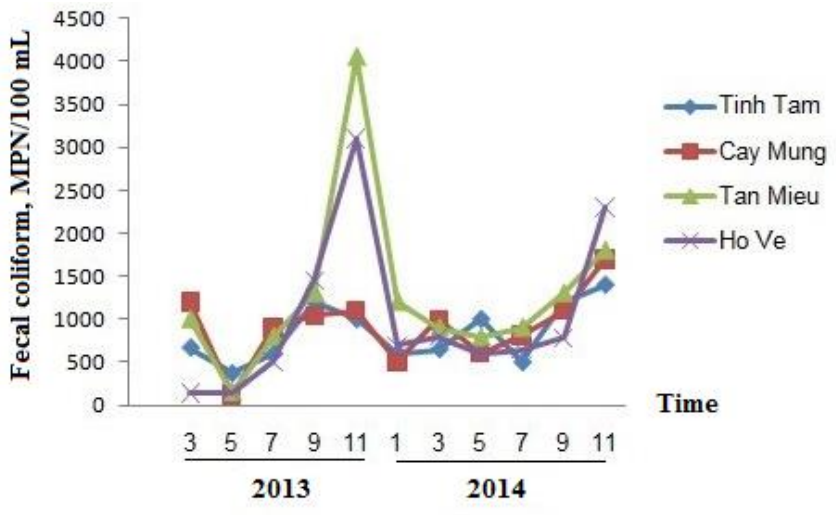

Figure 2. Fecal coliform levels at lakes in Hue Citadel

From TanMieu and HoVe Lakes, the fecal coliform levels of monitoring period in November (2013) have high values with 4050 and 3100 MPN/100 mL, respectively. Similarly, the fecal coliform levels observed in September (2014) at TinhTam, CayMung, TanMieu, HoVe lakes is quite high with respective values 1200, 1100, 1300 and 780 MPN/100 mL. The value of fecal coliform level at TinhTam Lake was 1400 MPN/100 mL whereas this value at CayMung Lake was 1700 MPN/100 mL during the monitoring time in November (2014). Fecal coliform level counts may be higher during wet periods versus dry periods. A wet season after the drought resulted in the higher loading of fecal coliform in the lake water.

Table 1 presents the monitoring results of fecal coliform levels at lakes in Hue Citadel. The observed fecal coliform level at TinhTam Lake has an average value of 835.5 ± 337.7 MPN/100 mL (n=11). Meanwhile, this value at CayMung Lake is from 120 to 1700 MPN/100 mL. Average values of fecal coliform levels at TanMieu and HoVe lakes are 1290.0 ± 1003.2 and 1015.5 ± 920.5 MPN/100 mL (n=11), respectively.

Table 1. Results of fecal coliform levels at lakes in Hue Citadel

Lake	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
TinhTam	11	835.5	337.7	101.8	370	1400
CayMung	11	915.5	412.7	124.4	120	1700
TanMieu	11	1290.0	1003.2	302.5	150	4050
HoVe	11	1015.5	920.5	277.5	140	3100

3.2. Varied trend of fecal coliform in lakes of Hue Citadel

The research used Mann-Kendall non-parametter test to examine and assess fecal coliform levels variation at lakes of Hue Citadel by ProUCL 4.1 software. The changing trend results of fecal coliform parameters in period 2013-2014 are shown in Figure 3(a-d).

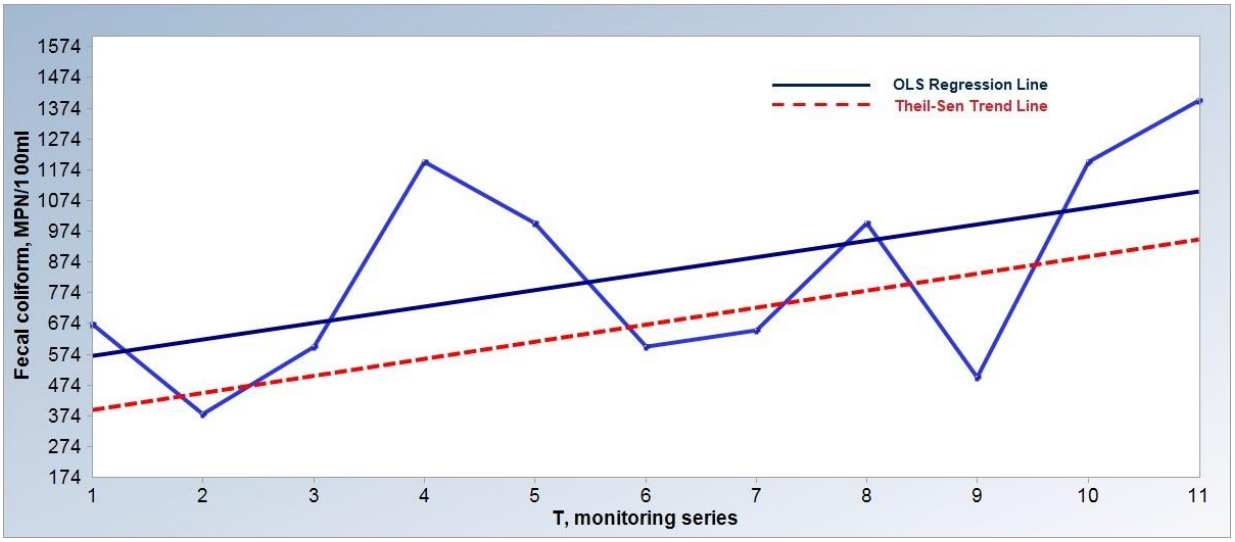

Figure 3a. Changing trend of fecal coliform at TinhTam Lake

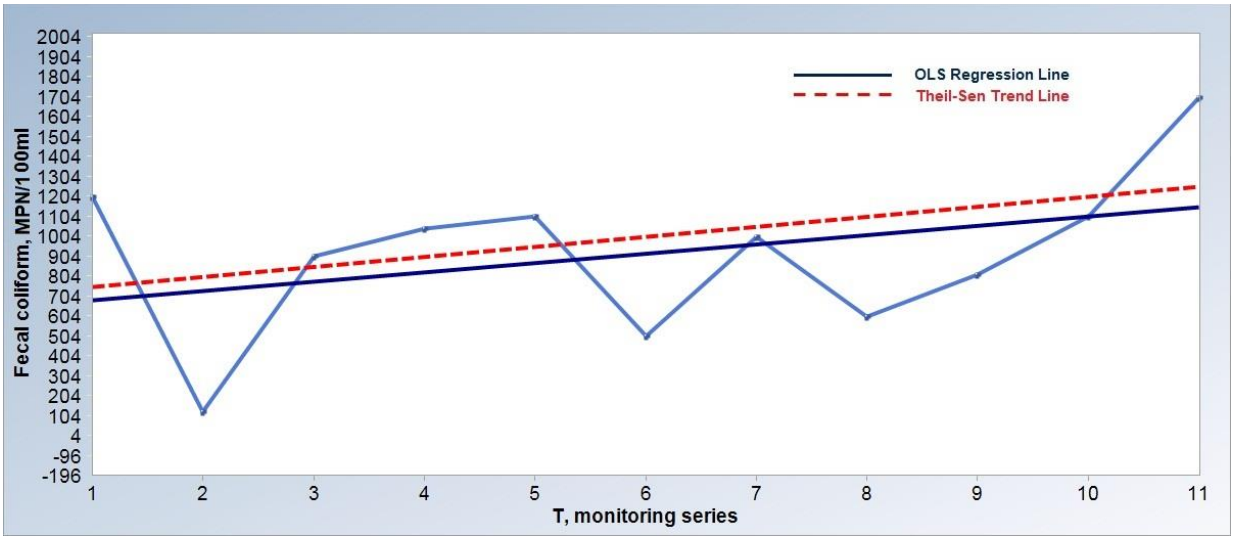

Figure 3b. Changing trend of fecal coliform at CayMung Lake

In statistics, the p-value is a function of the observed sample results and it is used for testing a statistical hypothesis. Before the test is performed, a threshold value (significance level) is chosen and traditionally α=1% to 5%. To test for the either upward or downward trend (a two-tailed test) at the α level of significance, Ho (there is no trend in the series) is rejected if $Z > Z\alpha/2$ or p-value < α. In this study, the significance level was chosen at 5% and using p-value calculated for Z, Ho is rejected if p-value < α. The detail results are shown in Table 2.

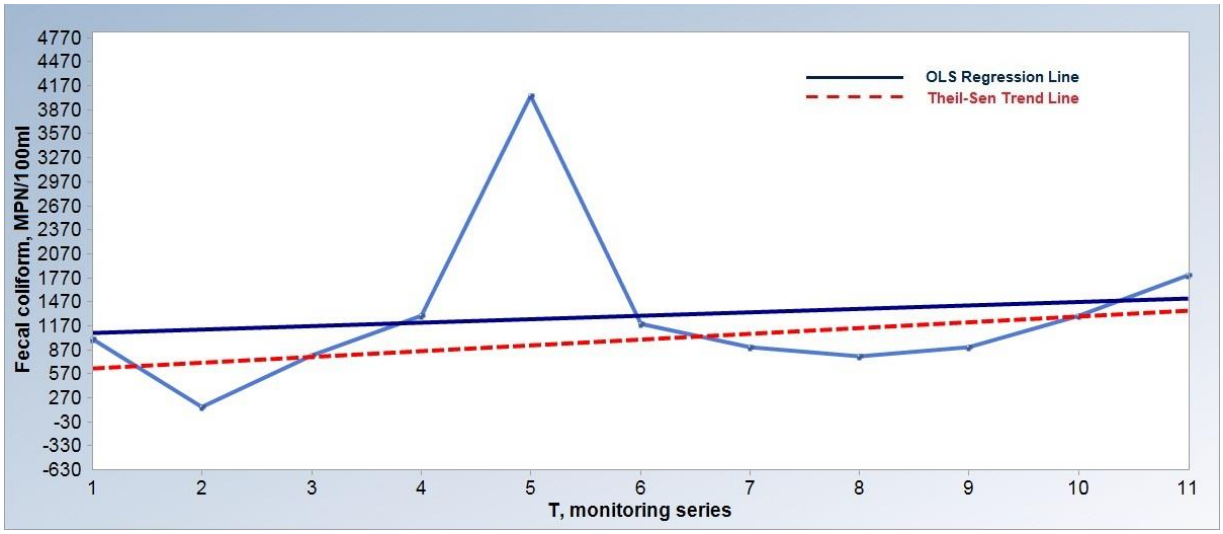

Figure 3c. Changing trend of fecal coliform at TanMieu Lake

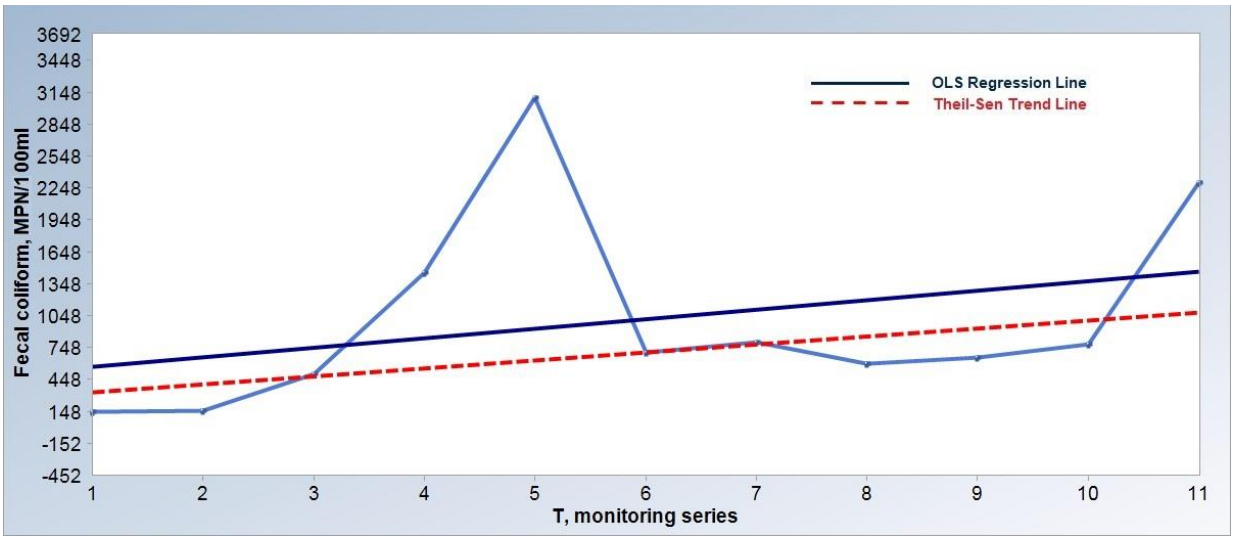

Figure 3d. Changing trend of fecal coliform at HoVe Lake

Trend analysis results of S value, Var S and Z in the lakes analyzed are shown in Table 2. The Mann-Kendall trend results of fecal coliform levels at HoVe Lake with S value, Var S, Z are 23.00; 12.85 and 1.713, respectively. Higher S Value was observed in this lake, which means the fecal coliform trend has the largest change of lakes system in Hue Citadel.

Table 2. Results of Mann-Kendall trend test of fecal coliform levels at lakes in Hue Citadel

Results	Fecal coliform (MPN/100 mL)			
	TinhTam	CayMung	TanMieu	HoVe
N	11	11	11	11
Min	370	120	150	140
Max	1400	1700	4050	3100
Mean	835.5	915.5	1290	1015.5
Standard Deviation (SD)	337.7	412.7	1003.2	920.5
Test value (S)	18.00	10.00	13.00	23.00
Standard Deviation of S (Var S)	12.73	12.81	12.77	12.85
Standardized value of S (Z)	1.336	0.703	0.940	1.713
Approximate p-value	0.0908	0.241	0.174	0.0434
Theil-Sen slope	57.50	50.00	71.43	75.00

According to the water quality standards of WHO and EPA, there cannot be any fecal coliforms in drinking water. Fecal coliform are a group of bacteria found in the fecal material of humans and other warm-blooded animals such as livestock, pets and wildlife. Density of birds may have a positive relationship with bacteria concentration, as they can be a source of fecal coliforms (Alderisio and Deluca, 1999). Table 1 shows the fecal coliform densities measured in lake waters. Overall, fecal coliform levels at lakes in Hue Citadel are quite high. The lakes with high mean fecal coliform counts were all small lakes like HoVe Lake, Tan Mieu Lake with 1015.5 (SD=920.5, n=11) and 1290.0 (SD=1003.2, n=11), respectively. Fecal coliform was present during all seasons in different lakes of Hue Citadel indicating that the water was contaminated by fecal material of humans or other warm-blooded animals. The source of fecal coliform contamination surface water in these lakes includes municipal wastewater discharges, septic leachate, storm runoff, wildlife populations, or non-point sources of human and animal waste. In addition, most of the fecal coliform monitoring stations have shown the water resources quality satisfied for low supplies. This means it just can use for purposes such as irrigation or waterway transport. Similarlly, the research of authors Nguyen et al. (2012) in Hue Citadel also shown the lakes' water pollution and it could not meet Vietnam surface water quality standard of class B1 in QCVN08:2008/BTNMT.

The monitoring data showed that fecal coliform level at TanMieu Lake is higher than at other lakes. Fecal coliform levels were compared at the surface for different sampling locations. An ANOVA was performed in the all stations to decide suitable sites which investigator of bacterial contamination. However, the ANOVA statistical analysis test results showed that there is no difference between them ($df=3$, $F=0.806$, $p > 0.05$). This means that the water quality fluctuations (Fecal coliform level) at lakes in Hue Citadel does not depend on geography factor. It could be said, the lakes had related to each other and were affected due to climate condition like precipitation, temperature, etc. The stormwater runoff is often identified as a source of coliform bacteria counts (McLellan and Jensen, 2003).

On the other hand, the statistical analysis results showed that fecal coliform level at HoVe Lake has varied with an increasing trend with statistical significance ($p < 0.05$). Figure 3(d) reports some results of the mentioned study, illustrating the mean fecal coliform map obtained using a statistical technique. Usually, the fecal concentration has an increasing trend in rainy season, especially in 2013. The big problem of waterborne diseases is relevant in many the developing countries. The impact of high concentrations of disease-producing organisms on water users can be healthy damage. Bacterial contamination of water, with regard to human health problems is a concern of people. Variations and trends of mean fecal coliform values time series were examined. The Mann-Kendall Rank Statistic Test was used for the examination of their significance (Kendall and Gibbons, 1990). The Mann-Kendall test gives interesting insight about fecal coliform data for the lakes in Hue City. The two-year monitoring study for fecal coliform in Hue Citadel showed a changing trend in lake water. The resultant Mann-Kendall test statistic (S) indicates how strong the trend in fecal coliform whether it is increasing or decreasing. The detailed results of fecal coliform levels Mann-Kendall trend analysis at lakes in Hue Citadel are shown in Table 2. The Mann-Kendall trend results of fecal coliform levels at Lake TinhTam with S value, Var S, Z are 18.00; 12.73 and 1.336, respectively. This increasing variation at TinhTam Lake does not have statistical significance ($p > 0.05$). In this case, the states of fecal coliform levels do not show statistically significant results. Results indicate that the trends observed in the increasing of fecal coliform are not similar. However, it could be suggest the fecal pollution control will reduce contaminated potential of runoff flowing into lakes in Hue Citadel.

In general, trend analysis results of fecal coliform levels at TinhTam, CayMung and TanMieu Lakes slightly increase, however, these results are not statistically significant ($p > 0.05$). In addition, the value of Theil-Sen slope at CayMung Lake has the value of 50.00. In contrast, Theil-Sen slope results at TanMieu and HoVe lakes have high value. Based on Theil-Sen slope, variation with increasing trend of fecal coliform levels at TanMieu Lake is about 35.71 MPN/100 mL/month (about 428.57 MPN/100 mL/year). Meanwhile, the trend of fecal coliform levels is quite high at HoVe Lake and reached 37.50 MPN/100 mL/month (450.00 MPN/100 mL/year, equivalent).

As mentioned above, there is sufficient evidence of a trend of increasing fecal coliform levels at HoVe Lake ($p < 0.05$). Fecal pollution statistics significantly increased over time in the station at HoVe Lake of Hue Citadel. This is explained by the growing population and increasing urbanization and industrialization the city, especially during the several last years. The decay of fecal coliform bacteria will be influenced on environmental quality factors. It means these lakes system is facing important trouble if there are no relevant necessary solutions to improve water quality by decline pollute resources into lakes.

4. CONCLUSIONS

This study provides baseline data on levels of bacterial indicator (fecal coliform), for a large population of lakes in Hue City. Overall, the fecal contamination levels have increasing trend in period 2013-2014. All analytical approaches used for this analysis show that fecal pollution has increased over the last two years in Hue Citadel. Specifically, the increasing trend of HoVe Lake's fecal coliform levels has statistical significance at $p < 0.05$ level. Theil-Sen trend line plotting indicates increasing trend in fecal coliform level for all studying stage equal about 450.00 MPN/100 mL/year. This increase in trends are alarming in regards to the current fecal contamination status in lakes of Hue Citadel. Therefore, to mitigate the contamination in these lakes systems, it is urgently required to implement practical

solutions to prevent the wastewater source to enter the water systems. It also requires widening flow cross-section to decrease contamination concentrations in lakes. In addition, the enhanced environmental awareness for local community also have an important role and effective function in general water quality protection process as well as lakes system in Hue Citadel. Regarding future challenges related to increased population and urban density in Hue City, which require the local government have to have water quality control programs.

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REFERENCES

Alderisio KA, DeLuca N. Seasonal enumeration of fecal coliform bacteria from the feces of ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). Applied and Environmental Microbiology 1999;65(12):5628-30.

American Public Health Association (APHA), AWWA, WEF. Standard Methods for the Examination of Water and Wastewater. 20th ed. Washington, DC: American Public Health Association; 1999.

Bouza-Deano R, Ternero-Rodrigues M, Fernandez-Espinosa AJ. Trend study and assessment of surface water quality in the Ebro River (Spain). Journal of Hydrology 2008;361:227-39.

Chiueh PT, Wu HT, Lo SL. Seasonal water quality trends in the Feitsui Reservoir watershed, Taiwan. World Academy of Science, Engineering and Technology 2011;58:497-500.

Faridah O, Alaa E, Ibrahim M. Trend analysis of a tropical urban river water quality in Malaysia. Journal of Environmental Monitoring 2012;14:3164-73

Heejun C. Spatial analysis of water quality trends in the Han River basin, South Korea. Water Research 2008;42:3285-304.

Hirsch RM, Slack JR, Smith RA. Techniques of trend analysis for monthly water quality data. Water Resources Research 1982;18(1):107-21.

Kendall MG, Gibbons JD. Rank Correlation Methods. 4th ed. London: Griffin; 1990.

Kostas V, Dimitra V. Water Quality Monitoring and Assessment. Rijeka: Publisher InTech Europe; 2012.

Nguyen MK. Monitoring and evaluating of water quality trend at Cu De River in the Da Nang City. Journal of Science, Can Tho University Part A: Natural Sciences, Technology and Environment 2014;34:100-7 (in Vietnamese).

Nguyen TCY, Pham KL. Assessment of trophic status of some lakes inside Hue Citadel using trophic indices. Journal of Science, Hue University 2012;75(6):267-72 (in Vietnamese).

Nguyen VH, Pham NAT, Nguyen HH, Vo TBV, Thuy CT. Water quality and eutrophic status of the lakes in Hue Citadel. Journal of Science, Hue University 2012;73(4):93-102 (in Vietnamese).

Le VT, Nguyen QH. Evaluation of water environment quality of some lakes in Hue city. Journal of Environment 2013;4:50-3 (in Vietnamese).

Lettenmaier DP. Detection of trend in water quality data from records with dependent observations. Water Resources Research 1976;12(5):1037-46.

McLellan S, Jensen E. Lake Michigan beaches: urban stormwater and water quality advisories. Lakeline 2003;23(2):27-9.

Ministry of Natural Resources and Environment (MONRE). National Standard TCVN 6663-3:2008 Water quality - Sampling - Guide of Sampling Preservation and Treatment. Hanoi: VMNRE (in Vietnamese). 2008.

Ministry of Natural Resources and Environment (MONRE). QCVN 08:2008/BTNMT: National Technical Regulation on Surface Water Quality. Hanoi: VMNR; 2008 (in Vietnamese).

Ministry of Natural Resources and Environment (MONRE). National Standard TCVN 6663-1:2011 Water quality – Sampling. Hanoi: VMNRE. 2011. (in Vietnamese).

Sateinpong K, Wasin I, Onanong P, Anukorn B, Kasem C. The coastal water quality change by effluent discharging from Phetchaburi municipal wastewater treatment system: the King's royally initiated environmental research and development project, Phetchaburi province, Thailand. Environment and Natural Resources Journal 2014 ;12(2):58-65.

Tran DAS, Vu HM. Lakes in Hue Citadel. Journal of Science and Technology, Thua Thien Hue Science and Technology Committee 1993;2:11-20 (in Vietnamese).

Taeng-On P, Isara T. Diversity of *Trichoptera* fauna and its correlation with water quality parameters at Pasak Cholasit reservoir, Central Thailand. Environment and Natural Resources Journal 2014;12(2):35-41.