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Water Quality Assessment in Selected Surface Waters in Can-Tho City, Vietnam

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Abstract: The study involves water quality assessment of the surface waters of Can Tho City, Vietnam. Water samples were obtained in six strategic sites. The mean pH values were within set Vietnam standards. The mean conductivity and Total Dissolved Solids (TDS) values were higher in low tides and in densely populated urban districts of An Hoa and An Cu. There are no set standard for Total Nitrogen (TN) and Total Phosphorus (TP) in Vietnam. But Mekong River Commission-Environmental Program of 2006 (MRC-EP) issued standards for TN and TP of values not exceeding 1.7 and 0.13 mg/L , respectively. Unfortunately, all sampling sites failed in these criterions. TN means in rural sites were 4.6 and 5.2 mg/L and in four urban sites, mean ranges from 8.6-10.1 mg/L . For TP, the rural and urban sites have means of 0.2 and 0.6 mg/L, respectively. In rural sites, the mean Dissolved Oxygen (DO) fall in B2 classification while Biological Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD) values in A2 classifications. This is worth looking into as communities in these rural sites use surface waters for domestic and agricultural needs. In urban sites, the COD and BOD_5 values fall in B1 classification while DO mean values were way beyond the set Vietnam's maximum tolerable limits. The national and local government may review and assess the management of its water resources. To have a sustainable economic development in agriculture, food safety and security, human health and safety, sustainable water resource management is necessary.

Key words: Can Tho City, biological oxygen demand, dissolved oxygen, total nitrogen, total phosphorus, necessary

INTRODUCTION

Water quality issues are one of the major challenges developing countries in Southeast Asia are facing right now, especially in the implementation of ASEAN Free Trade Agreement (AFTA). Water quality of water resources will not only affect human and environmental health but also economic growth and sustainability.

Can Tho City, Vietnam is located in the downstream of the Mekong Delta. There are 158 rivers and canals in the city with deteriorating water quality (Brown *et al*., 2009). If this water quality problem left unsolved it will worsen in a few years that will affect the economic development in agriculture, tourism, food safety and security, human health and livability.

The water resources in the city are also affected by frequent flooding, worsen by climate change. The floods in the city were due to seasonal flooding of Mekong River, tidal effect, heavy rains in the months of June-October or combination of two or three factors. Vietnamese living along the delta are adapted with flood and can even live with it. The adaptability of Vietnamese should not be a reason not to think of mitigating measures.

For the sustainable utilization and protection of water resources of Can Tho, local government and concern government agencies in the city should create a realistic legal framework that adhere or complements national regulations (Loan, 2010). It needs a sustainable water resource management framework that includes feasible and efficient treatment and disposal of waste water from households, industries and agriculture.

Deteriorating water quality and shortage of water supply are also intensified by anthropogenic activities of rapid population growth in urban areas (Ozaki *et al*., 2014; Schwarzenbach *et al*., 2010). This is not isolated only to Vietnam but also to other developing

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countries (Anh *et al*., 2010; Bambrick *et al*., 2011). To address the deteriorating water quality of the surface waters of Can Tho this study assessed the water quality of 6 established surface waters in the city.

MATERIALS AND METHODS

Study site: The actual water sampling sites in Can Tho, Vietnam are s hown in red dots in Fig. 1. The sites are the following: N1 Nhon Nghia in Tinh Lo 932 and N2 Nhon Nghia in Thanh Pho Can Tho in Phong Dien District, H1 An Hoa in Durong Huynh Thuc Khang 214, H2 An Hoa in Durong Huynh Thuc Khang 128B, C1 An Cu in Thanh Pho Can Tho and C2 An Cu in Durong De Tham 100 A in Nien Kieu District.

Sampling and analytical methods: Water samples were collected in the established sampling sites for the months of December 2013 and January 2014. Water quality parameters measured in-situ were pH by WTW pH meter 340i, Total Dissolved Solids (TDS), conductivity and salinity by WTW conductivity meter LF 330i, Dissolved

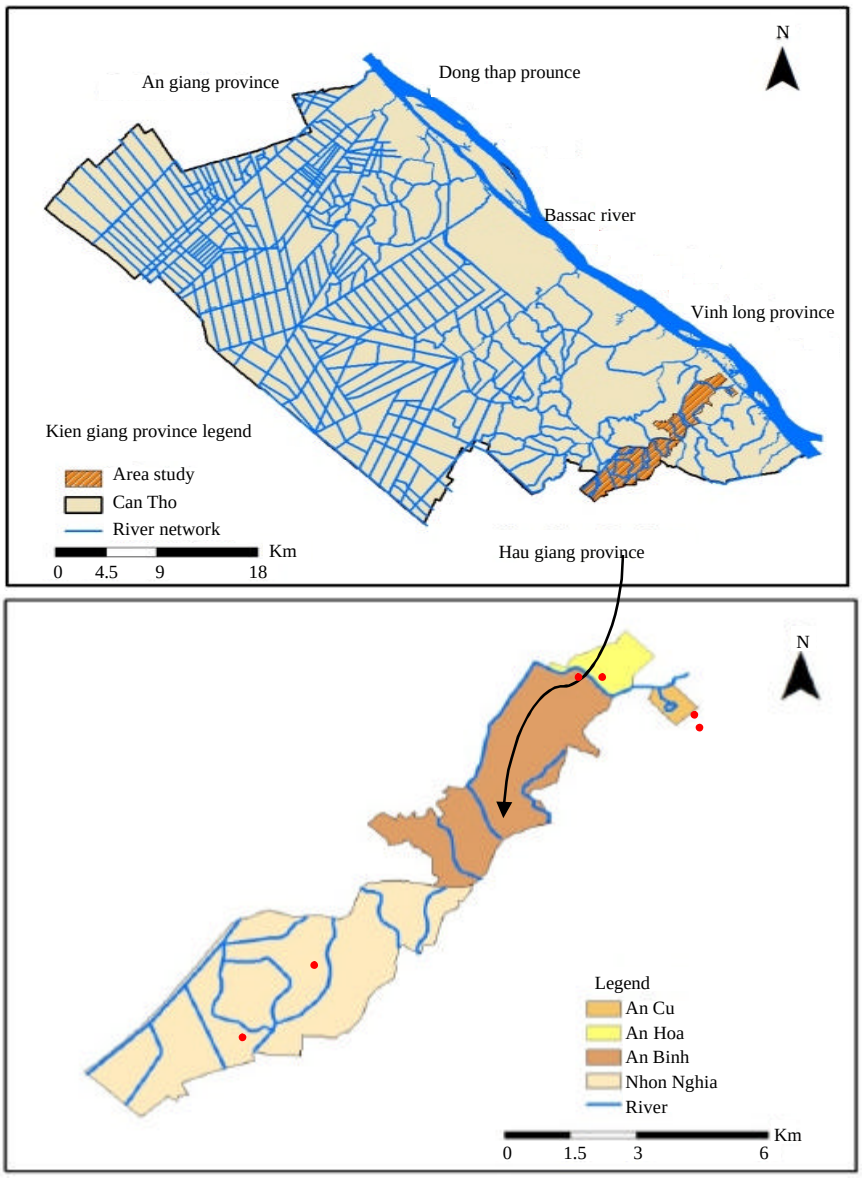

Fig. 1: Research sampling sites in Can Tho, Vietnam

Oxygen (DO) and temperature by WTW Oxygen meter Oxi 340, Cadmium Reduction Method (powder pillows) for nitrates and Phos Ver 3 Ascorbic Acid method for phosphates. While, Total Nitrogen and Phosphorus (TN and TP) Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5) in the accredited laboratory of Can Tho University.

Statistical analysis: The data were then compared statistically. F-test was used to test the equality of variances and t-test was used to know the significant difference of means between two sampling sites within the same community. Two-way Analysis Of Variance (ANOVA) at 0.05 level of significance was used to know the significant difference of means of the six sampling sites and 33 sampling periods. Tukey's Honest Significant Difference (HSD) was used to identify which mean was significantly different to other means.

RESULTS AND DISCUSSION

The surface water standard of Vietnam have four classifications, namely, A_1 for water supply, A_2 for aquatic plants, B_1 for irrigation and B_2 for traffic. The mean values obtained in this study are shown in Table 1. The values were then compared to the set Vietnam standards and the Mekong River Commission-Environmental Program (MRC-EP) in 2006 standards as shown in Table 2.

The mean pH values in 33 sampling periods at 25°C for the 6 sampling sites were within standards set by Vietnam. Variations in pH values were not observed in this study as compared to the study conducted on hourly basis on different geographical location of the canals in Can Tho (Trinh *et al*., 2010).

Using f-test and t-test the means within Nhon Nghia and An Cu were not significantly different. Two way ANOVA showed significant differences between six means. Tukey's HSD results showed that mean of H1 was significantly different to the means of N2, H2 and C1. The temperature ranges of six sampling sites were: 4.8 and 3.4°C for Nhon Nghia; 8.0 and 7.7°C for An Hoa and 4.2 and 4.8°C for An Cu. The temperature ranges per sampling site exceeded the three degree rise as commonly used by other countries.

Verifying further the temperature ranges the values obtained were compared to the 5 years climate temperature trends of Can Tho in 2005-10. As seen in the recorded 5 year climatic temperature trend the ranges were 10.4-12.7°C. The ranges for the months of January and December were 12.7 and 12.2°C, respectively

Table 1: Mean values of water quality parameters in 6 sampling sites in three districts in Can Tho

	Nhon Nghia		An Hoa		An Cu	
Water quality parameters	N1	N2	H1	H2	C1	C2
pH	7.12	7.18	7.08	7.16	7.16	7.14
T°C	26.4	26.7	26.5	26.7	27.0	27.1
Cond (µs/cm)	146	146	315	354	238	258
TDS (mg/L)	105	108	224	246	173	184
TN (mg/L)	4.6	5.2	9.1	10.1	8.6	8.7
TP (mg/L)	0.20	0.20	0.60	0.60	0.60	0.60
NO_3^{1-} (mg/L)	0.70	1.10	0.70	1.20	1.20	0.40
PO_3^{3-} (mg/L)	0.07	0.07	0.24	0.17	0.14	0.14
DO (mg/L)	2.3	2.9	0.8	0.7	1.2	1.3
COD (mg/L)	16.5	15.1	31.5	30.5	29.9	33.4
BOD (mg/L)	5.0	5.2	8.8	9.7	9.1	10.5

Table 2: Vietnam and MRC-EP standards

	Classification			
Water quality parameters	A1	A2	B1	B2
pH	6.0-8.5		5.0-9.0	
T°C	No set standard			
Cond (µs/cm)	No set standard			
TDS (mg/L)	No set standard			
TN (mg/L)	MRC-EP Std. <1.7			
NO_3^{1-} (mg/L)	2	5	10	15
TP (mg/L sec)	MRC-EP Std. <0.13			
PO_3^{3-} (mg/L)	0.1	0.2	0.3	0.5
DO (mg/L)	≥6	≥5	≥4	≥2
COD (mg/L)	10	15	30	50
BOD (mg/L)	4	6	15	25

(Leloup *et al*., 2013). High temperature ranges were quite normal in the city. The observed temperature ranges in this study correlates with the climatic temperature to a certain degree. So, the values obtained were within the normal temperature ranges of Can Tho.

F-and t-tests showed no significantly difference between the temperature means of the 2 sampling sites within communities. ANOVA 2 way showed significant difference between six means. Tukey's HSD showed C1 and C2 differed from N1, N2, H1 and H2. The mean values were affected by the nature of surface waters. Flowing water bodies like Nhon Nghia and An Hoa (N1, N2, H1 and H2) had lower temperatures compared to stagnant water body, An Cu (C1 and C2).

The mean conductance values were higher in low tides in all sampling sites. Higher conductance values were obtained in the densely populated districts. An Hoa had conductance means of 315 and 354 μs/cm while An Cu had 238 and 258 μs/cm. In the suburban community of Nhon Nghia, c onductance means in two sites were 146 μs/cm.

Although, conductance has no set standard, it was also necessary to know its value as salt intrusion or transport of other pollutants can be monitored by knowing variations of values (Ford *et al*., 2005).

Using f-and t-tests the conductance means within communities were the same. The ANOVA 2 way showed significant difference in both sampling periods and sites. Using Tukey's HSD, results showed that conductance means within established community were the same but the means of one community differed significantly from other communities, even within the same district.

Total Dissolved Solids (TDS) mean values in ppm or mg/L were also affected by low tides. Similar with conductance, higher TDS values were obtained in the densely populated districts of An Hoa and An Cu. An Hoa had TDS means of 224 and 246 mg/L and An Cu had 173 and 184 mg/L. The suburban district of Nhon Nghia had TDS means of 105 and 108 mg/L.

Higher values of conductance and TDS in urban districts were greatly influenced by domestic wastes. Some residents in these districts threw wastes directly into the surface waters as visibly seen in the whole duration of the study.

Using f-and t-tests the TDS means within communities were not significantly different. The ANOVA 2 way showed highly significant both in sampling periods and sites. Using Tukey's HSD, results showed that TDS means differ significantly with the means of other communities.

Total Nitrogen (TN) and Phosphorus (TP) in surface water have no set standard in Vietnam. But MRC-EP issued standard values for TN and TP of values not exceeding 1.7 and 0.13 mg/L, respectively (Trinh *et al*., 2010). Unfortunately, all sampling sites failed in these criterions. Considering that the values obtained in this study were obtained at the time when the water was at the daily high tide thus diluted. This was based on the 17 sampling stations established in Can Tho (Trinh *et al*., 2010).

High values of TN and TP were obtained in the established urban sampling sites of An Cu and An Hoa. Domestic wastes contributed so much to these high values. Based on Can Tho Statistics in 2011, 799,859 people reside in the urban areas as compared to 409,333 in the rural areas (Leloup *et al*., 2013). For sub-urban/rural district, agricultural and domestic wastes were the sources of pollution (Anh *et al*., 2010; Silva *et al*., 2010; Leloup *et al*., 2013; Ma *et al*., 2011).

Agriculture accounts for 82% of Can Tho's land use and fertilizers were main source of nitrogen and phosphorus pollutant (Silva *et al*., 2010; Leloup *et al*., 2013; Verhoeven *et al*., 2006). In aquaculture production, 1000 kg of frozen fillet of catfish produced 106 kg nitrogen, 27 kg phosphorus, 740 kg BOD, 1020 kg COD and 2050 kg TSS (Anh *et al*., 2010). Studies showed that increase in phosphorus concentration produce algal bloom and increase the growth of bacteria (Le *et al*., 2010; Thingstad *et al*., 2005).

F and t-tests showed no significantly difference between the means of TN and TP in 2 sampling sites within communities. ANOVA showed significant difference between sampling sites and periods. Tukey's test showed that N1 and N2, located in an agricultural setting were significantly different with the densely populated urban sampling sites, H1, H2, C1 and C2.

The average nitrate concentrations in all sampling sites fall in A1 classification. The obtained values in nitrates were within the set Vietnam's standard of 2 ppm for A1 and would mean good water quality. The nitrates values failed in the MRC-EP s tandard of <1.7 ppm for TN.

Vietnam has no set standard for TN but it should be considered that TN summed up all the nitrate-nitrogen (NO_3-N), Nitrite-Nitrogen (NO_2-N), Ammonia-Nitrogen (NH_3-N) and organically bonded nitrogen concentrations. So nitrates values should be lesser than TN.

In agricultural country like Vietnam, knowing the nitrate concentrations in surface water was essential in this study. Farmers used fertilizer that contained nitrates for biological needs of plants. Nitrates as agricultural wastes entered fresh water that caused depletion of oxygen. And with high bacteria in water, nitrites can be converted to nitrates.

The values of nitrates for drinking water were important to the communities of Nhon Nghia as they used the surface water for drinking and cooking food. While quite a number of An Binh residents, living along the floating market, used surface water for drinking and cooking food during flooding.

The t-tests showed no significant difference in means within communities, using ANOVA, the p-value showed no significant difference between sampling sites and periods. The average phosphate values for the suburban communities of Nhon Nghia, N1 and N2, fall in A1 classification. While the 4 sampling sites in the urban communities, H1, H2, C1 and C2, qualified for A2. Using Vietnam's standard the phosphates values obtained showed good water quality. But, the set phosphate standards were very high compared to the standard issued by the MRC-EP of not more than 0.13 mg/L for TP. If MRC-EP was followed then phosphates values obtained in sampling sites N1 and N2 passed. But it should be considered that Total Phosphorus (TP) summed up all forms of inorganic phosphate. TP should have higher values than phosphates.

Using F and t-tests the means within communities were not significantly different. But with ANOVA 2 way the means were not significantly different in sampling periods but significantly different between sampling sites. Tukey's tests showed that the means of N1 and N2 were significantly different with the means of H1, H2, C1 and C2. The mean of H1 was significantly different to the other means. The average DO values in mg/L in 2 sampling sites in Nhon Nghia fall in B2 classification. While the 4 sampling sites in two urban sites of An Hoa and An Cu were way beyond the maximum tolerable limit set by Vietnam.

The DO values obtained in this study were acquired in its lowest concentration or at daily high tide (Trinh *et al*., 2010). The DO values also varied with temperature. The temperature ranges in this study, did not affect much the DO values. Low DO values in this study were very alarming, especially in the communities of Nhon Nghia that used surface waters for domestic and agricultural needs. Studies showed that DO value of 2-3 mg/L, increased the decomposition of young marine and river-borne biogenic substance as well as old residual organic matter (Chen *et al*., 2007). Stagnant or stored water source with low DO values increased the release of iron in corroded water pipes (Sarin *et al*., 2004).

Using F-test and t-test the DO means within communities of An Hoa and An Cu were not significantly different but significantly different in Nhon Nghia. The ANOVA 2 way showed significant difference with the means in different sampling sites. Tukey's test revealed significant differences in the means of N1 and N2 to all other means C1 and C2-H1 and H2. Looking at the means of the sampling sites, N1 and N2 the values were much higher than the means of the other sampling sites.

COD values showed the measured oxygen required to oxidize all compounds in water. This includes both organic and inorganic compounds. COD measurement were often preferred than the lengthy BOD (Silva *et al*., 2010).

The COD means of sampling sites, N1 and N2, fall in A2 classification for surface water. While the other four urban sampling sites, H1, H2, C1 and C2 fall in B1 classification. The average COD values in this study were much higher than the values obtained by the monitoring group of Can Tho in the same months (Monitoring, 2013). It should be taken into consideration that the monitoring group has sampling stations above and lower than the established sampling stations of this study.

High COD values were obtained in the densely populated districts of An Hoa and An Cu. An Hoa had COD means of 31.5 and 30.5 mg/L and An Cu had 29.9 and 33.4 mg/L . The suburban district of Nhon Nghia had COD means of 16.5 and 15.1 mg/L. High COD values correlate health hazard to human. The high values connote possibilities of algal bloom, seafood contamination and bacterial load from organic wastes. The same sampling sites had low DO values (<3 mg/L), hypoxia can cause death to aquatic organisms and at the same time releases pollutants that settled in the riverbanks or sediments.

Using F and t-tests the means within the same community were not significantly different. ANOVA test showed significant differences in sampling periods and sites. Tukey's test showed that the means of the sub-urban sampling sites, N1 and N2 were significantly different with the urban sampling sites, H1, H2, C1 and C2. BOD_5 determined the amount of dissolved oxygen needed by aerobic biological organisms in a body of water. The process was lengthy as this involved the breakdown of organic material in a given water sample at certain temperature (20°C) over a specific time period 5 days.

Just like in COD, high BOD values were obtained in the densely populated districts of An Hoa and An Cu. An Hoa had BOD means of 8.8 and 9.7 mg/L and An Cu had 9.1 and 10.5 mg/L . The suburban district of Nhon Nghia had BOD means of 5.0 and 5.2 mg/L . BOD_5 values in the urban communities of An Cu and An Hoa fall in the B1 classification.

High BOD_5 values indicated the amount of putrescible organic matter present in the surface water and indicated polluted water. The values showed that

large amount of bacteria were present in water that also consumed oxygen dissolved in water. Thus, gave very low DO values.

High mean values of BOD_5 in four urban sampling sites would mean that the urban surface waters in Can Tho were more contaminated with greater amount of bacteria than the agricultural communities of Nhon Nghia. The BOD_5 values obtained in this study were not significantly different with the values obtained by the monitoring group on the same month (Monitoring, 2013).

F and t-tests showed that the BOD_5 means within the same community were not significantly different. ANOVA test showed high significant differences in the sampling periods and sites. Tukey's test showed that the means of the sub-urban sampling sites, N1 and N2 were significantly different with the urban sampling sites, H1, H2, C1 and C2. And of the four urban sampling sites, C2 with the highest BOD_5 value was significantly different with the two lower BOD_5 values, H1 and C1.

CONCLUSION

The mean pH values and temperature ranges were within standards set by Vietnam. The mean conductivity and TDS values were higher in low tides in all sampling sites. Higher conductivity and TDS values were obtained in the densely populated districts of An Hoa and An Cu where domestic wastes were visibly seen on the surface waters during the whole duration of the study. Conductivity has no standard but necessary to know as salt intrusion or other pollutants can be monitored by knowing variations of values.

At the time of the study there were no set standard for TN and TP in Vietnam. But MRC-EP issued standard values for TN and TP of values not exceeding 1.7 and 0.13 mg/L, respectively. Unfortunately, all sampling sites failed in these criterions. High values of TN and TP were obtained in the established urban sampling sites of An Cu and An Hoa as compared to the suburban sampling sites of Nhon Nghia.

The average nitrate concentrations in all sampling sites fall in A1 classification of 2 ppm which would mean good water quality. The average phosphate values of Nhon Nghia, N1 and N2, fall in A1 classification while the four urban sampling sites, H1, H2 , C1 and C2, qualified for A2. But the values were very high compared to the TN and TP standard issued by the MRC-EP.

The mean DO values in mg/L in Nhon Nghia sampling sites fall in B2 classification while the other values were way beyond the maximum tolerable limit. The COD mean values in the suburban areas fall in A2 classification. This study find it necessary to measure the DO and COD values in the communities where surface waters for domestic and agricultural needs.

COD and BOD_5 values in the urban communities fall in B_1 classification. These values mean that the urban sampling sites were more polluted or contaminated than the suburban sampling sites. And connote possibilities of algal bloom, contamination and high bacterial load.

The Vietnamese should be informed on the deteriorating water quality of the surface waters in Can Tho. As observed, Vietnamese love to eat raw vegetable locally produced by farmers in the rural districts that were washed by surface water in the canals or river.

The national and local government may start reviewing and assessing the management of its water resources. To have a sustainable economic development in agriculture, sustainable water resource management is necessary. It is high time for the government not only to monitor the water quality but should impose strict compliance on set standards.

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REFERENCES

Anh, P.T., C. Kroeze, S.R. Bush and A.P. Mol, 2010. Water pollution by pangasius production in the Mekong Delta, Vietnam: Causes and options for control. Aquacult. Res., 42: 108-128.

Bambrick, H.J., A.G. Capon, G.B. Barnett, R.M. Beaty and A.J. Burton, 2011. Climate change and health in the urban environment: Adaptation opportunities in Australian cities. Asia Pac. J. Public Health, 23: 67-79.

Brown, R.R., N. Keath and T.H.F. Wong, 2009. Urban water management in cities: Historical, current and future regimes. Water Sci. Technol., 59: 847-855.

Chen, C.C., G.C. Gong and F.K. Shiah, 2007. Hypoxia in the East China Sea: One of the largest coastal low-oxygen areas in the world. Mar. Environ. Res., 674: 399-408.

Le, C., Y. Zha, Y. Li, D. Sun and H. Lu et al., 2010. Eutrophication of lake waters in China: Cost, causes and control. Environ. Manage., 45: 662-668.

Leloup, V., L.Z. Razafindrazay, N.H. Dzung and K.Q. Vinh, 2013. Can Tho, Vietnam comphrehensive resilience planning for integrated flood risk management SCE QA project no 12060. World Bank, Australia.

Loan, N.T.P., 2010. Problems of law enforcement in Vietnam: The case of Wastewater management in Can Tho City; ZEF working paper series. Master Thesis, University of Bonn, Bonn, Germany.

Ma, X., Y. Li, M. Zhang, F. Zheng and S. Du, 2011. Assessment and analysis of non-point source nitrogen and phosphorus loads in the Three Gorges Reservoir Area of Hubei Province, China. Sci. Total Environ., 412: 154-161.

Monitoring, C.T.E., 2013. Environmental monitoring monthly report. Can Tho Center for Natural Resource and Environment Monitoring, Can Tho City, Vietnam.

Ozaki, H., A.K. Le, V.N. Pham, V.B. Nguyen and M. Tarao et al., 2014. Human factors and tidal influences on water quality of an Urban River in Can Tho a major city of the Mekong Delta, Vietnam. Environ. Monit. Assess., 186: 845-858.

Sarin, P., V.L. Snoeyink, J. Bebee, K.K. Jim, M.A. Beckett, W.M. Kriven and J.A. Clement, 2004. Iron release from corroded iron pipes in drinking water distribution systems: Effect of dissolved oxygen. Water Res., 38: 1259-1269.

Schwarzenbach, R.P., T. Egli, T.B. Hofstetter, U.V. Gunten and B. Wehrli, 2010. Global water pollution and human health. Annu. Rev. Environ. Res., 35: 109-136.

Silva, S.S.D., B.A. Ingram, P.T. Nguyen, T.M. Bui and G.J. Gooley et al., 2010. Estimation of Nitrogen and Phosphorus in effluent from the striped catfish farming sector in the Mekong Delta, Vietnam. Ambio, 39: 504-514.

Thingstad, T.F., M.D. Krom, R.F.C. Mantoura, G.F. Flaten and S. Groom et al., 2005. Nature of phosphorus
limitation in the ultraoligotrophic Eastern Mediterranean. Sci., 309: 1068-1071.

Trinh, T.L., P.V.D. Steen and P. Lens, 2010. Wastewater Reuse Toward Adaptation to Climate Change in the Mekong Delta, Vietnam (Wwar-Acc). UNESCO-IHE, Delft, Netherlands.

Verhoeven, J.T., B. Arheimer, C. Yin and M.M. Hefting, 2006. Regional and global concerns over wetlands and water quality. Trends Ecol. Evol., 21: 96-103.