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Characteristics of "Black Water" in Lung Ngoc Hoang Natural Reserve, Phung Hiep District, Hau Giang Province, Vietnam

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Abstract

The study was conducted to evaluate the characteristics of black water arising in the rainy season at Lung Ngoc Hoang Nature Reserve, Phung Hiep District, Hau Giang Province. Water samples were collected at the strictly protected area and the ecological rehabilitation area of Lung Ngoc Hoang Nature Reserve. Black water is evaluated using the parameters of temperature, turbidity, DO, TSS, H_2S, EC, BOD, COD, NH_4^+-N, NO_2^--N, NO_3^--N, PO_4^{3-}-P, SO_4^{2-}, TN, TP, Fe^{2+}, Al^{3+}, lignin, and coliform. The values of these parameters are compared with those in QCVN 08-MT: 2015/BTNMT, column A1. The study results showed that black water appears in rainy months from June to October from forest areas plot 6 and plot 85 where are small channels and poor flow. The results of water quality analysis showed that BOD, COD, TSS, TP and TN parameters all exceeded the allowable thresholds, especially DO was very low compared to the standard from 20 to 21 times. Al^{3+} and Fe^{2+} are both higher than the permissible limits. Water is seriously polluted and can affect aquatic life in the study area.

1.0 Introduction

Lung Ngoc Hoang Nature Reserve was established by Decision No. 13/2002/QD-TTg dated January 14, 2002 of the Prime Minister. It is the last heritage of a famous natural ecosystem, including the land scope of Phuong Ninh Forest Enterprise in Phung Hiep district, Can Tho province, now in Phuong Binh commune, Phung Hiep district, Hau Giang province. The total area of the reserve is 2,805.37 ha, including strictly protected area: 976.28 ha, ecological rehabilitation zone: 963.45 ha, administrative, service and tourist area: 404, 61 ha, scientific experimental area: 461.03 ha. The buffer zone of Lung Ngoc Hoang Nature Reserve covers an area of 8,836.07 ha. Lung Ngoc Hoang Wetland Nature Reserve is located at the junction between two ecological zones west of Hau river and Ca Mau peninsula. West of Hau river is the common name for the land on the west bank of Hau river, bordering the Long Xuyen Quadrangle by Cai San canal, connected with Ca Mau peninsula by Cai Con - Lai Hieu canal and Cai Lon-Cai Be river system. Lung Ngoc Hoang's natural environmental features have a very close relationship with the western region of the Hau river and the Ca Mau peninsula. This region is formed by sea recoil and alluvial deposition, mainly coastal sediments and swamps, forming a low and fairly flat terrain, with average elevation varying from 0.3 to 1.5 m and separated by a system of canals. Lung Ngoc Hoang Nature Reserve is considered one of the important wetland ecological reserves in Vietnam. The flora and fauna in Lung Ngoc Hoang NR are quite diverse, with more than 978 species discovered. As of 2017, there were 352 species of higher plants, 57 species of fungi, 59 species of terrestrial animals, and the spider group recorded 61 species, 100 species of insects, 13 species of molluscs, 20 species of benthic animals.

In addition, there were 78 species of blue-green algae and 95 species of green algae, 75 species of fish present in the water bodies of Lung Ngoc Hoang Nature Reserve. In addition, the study also recorded 72 bird species, of which 21 new species appeared at Lung Ngoc Hoang, among the flora and fauna species found in the Reserve. The dominant flora is melaleuca forest. In addition to higher animals, there are also land animals, which are mainly invertebrates, which play an important role in the metabolism of the ecosystem. Soil fauna is an important part of biodiversity and plays an essential role in several functions of soil ecosystems. Furthermore, these species are considered as soil quality indicator animals. Every year, after growing and developing melaleuca forest ecosystem, a large amount of organic matters will be returned to the soil through the process of decomposing fallen vegetation such as branches and dry leaves of melaleuca trees. The amount of vegetation will decompose into organic components that provide the soil to nourish the plant. However, this amount of vegetation is a concern for the area, when in the dry season it will be the main pressure for forest fire management and prevention because this amount of vegetation is thick and dry, easily igniting. Retaining water to protect forests during the dry season helps to limit forest fires is a solution for fire prevention and fighting. Lung Ngoc Hoang has been applying this solution, with the system of storing water in forest plots to prevent fire in the dry season. However, water could accumulate several types of pollutants from the forest. In the rainy season, when water is washed away and flowing into the canals of the conservation area, the water on the rivers turns black, affecting the aquatic system. In the past, there have been some studies on melaleuca forests and the hydro-chemical characteristics in areas in melaleuca forests. However, available information on characteristics of black water is limited. This study characterized water quality and spreading areas of the black water in the Lung Ngoc Hoang NR, Phung Hiep district, Hau Giang province. The present study results could be very helpful for water quality management strategy.

2. Materials and methods

2.1 Water sampling and analysis

Water sampling is carried out at two locations in strictly protected functional areas (plot 85) and ecological restoration functional area (plot 06) shown in Table 1.

Table 1. Description of the sampling locations

No.	Code	Coordinates		Area	Brief description
		X	Y		
1.	NN01	105.71824	9.7235	Strictly protected functional areas	This is the forest protection area, flora communities, swamp ecosystems and typical landscapes of the floodplain.
2.	ST01	105.67164	9.7209	Ecological restoration functional area	This is an area that protects and regenerates forests, restores wetland ecosystems, is an area closely managed and protected for the forest to be restored and regenerated naturally.

The water quality parameters of temperature, pH, EC, DO were measured directly in the field. The parameters of turbidity, TSS, H_2S, BOD, COD, NH_4^+-N, NO_2^--N, NO_3^--N, PO_4^{3-}-P, SO_4^{2-} TN, TP, Al^{3+}, Fe^{2+}, lignin, coliform were analyzed at the laboratory according to standard methods [1] (Table 2). Water sample analysis results were compared with QCVN 08-MT: 2015/BTNMT [2] to assess surface water quality.

Table 2. Analytical methods of water samples

No.	Parameters	Description	Brief analytical method description
1	Temp.	Temperature	Temperature meter, AD332 ADWA
2	pH	pH	pH meter, HM-31P, TOADKK
3	Turb.	Turbidity	Turbidity meter, TL2300.HACH-USA
4	EC	Electrical conductivity	EC meter, EC/TDS COM-100 HM Digital
5	TSS	Total suspended solids	Filtration method
6	DO	Dissolved oxygen	DO meter, DO-31P, TOADKK
7	BOD	Biological oxygen demand	Incubation method
8	COD	Chemical oxygen demand	Sample digestion and colorimetric method
9	H_2S	Hydrogen sulfide	Precipitation method
10	NH_4^+-N	Ammonium nitrogen	Colorimetric method
11	NO_2^--N	Nitrite nitrogen	Colorimetric method
12	NO_3^--N	Nitrate nitrogen	Colorimetric method
13	TN	Total nitrogen	Sample digestion and titration methods
14	PO_4^{3-}-P	Orthophosphate	Colorimetric method
15	TP	Total phosphorus	Colorimetric method after sample digestion
16	SO_4^{2-}	Sulfate	Precipitation method
17	Fe^{2+}	Iron divalent	Colorimetric method
18	Al^{3+}	Aluminum trivalent	Titration method
19	Lignin	Lignin	Using spectrophotometer at specific wavelength
20	Coliform	Coliform	Counting using MPN method

3. Results and discussion

3.1 Generation of black water in the study area

Lung Ngoc Hoang Wetland Nature Reserve is considered to be a place with a low-lying system combined with strictly managed melaleuca forest, creating a suitable environment for many species of flora and fauna to grow, especially the protected area for biodiversity resources protection. However, at present, the water source in Lung Ngoc Hoang NR has been affected and shows signs of water pollution, greatly affecting the life, economy and society of the communities in the buffer zone as well as the public. In addition, in the strict area during the rainy season, black water appears, affecting the aquatic life in the area. Black water can be generally understood as rain water that accumulates in forest in the rainy season after the organic decomposition process. Undergone vegetative decomposition and physical and chemical degradation of wetlands during the dry season, the water condenses and turns black. In the following rainy seasons, black water is washed away from the canals, making the water in these canals turn black, and local people call the water as "black water". The appearance of black water must go through many stages and black water generation cycle is shown in Figure 1. The cycles included the stages of vegetation decomposition, generation and accumulation of black water and finally the spread of the black water across the canals in the conservation area. Every year, the vegetative layer includes the fallen materials of plants, mainly the bark and leaves of melaleuca trees. The decomposition of the vegetation lasts 12 months, but the period from January to April (dry season) is when the vegetation decomposes and the black fluid accumulates. The area is submerged, anaerobic decomposition of the fallen debris occurs. At the beginning of the rainy season (June), the rainfall and stagnant water make the vegetation completely decomposed, releasing compounds containing sulfide and suspended residues. These compounds form black water and this water is flowed down the canal resulting the surface water source turning black. Then, the black water spreads in forest areas and lasts through the rainy season. The period from September to December (the rainy season), the black water to spread to the neighboring areas due to high rainfall and tidal scheme. The distribution range of black water is shown in Figure 2.

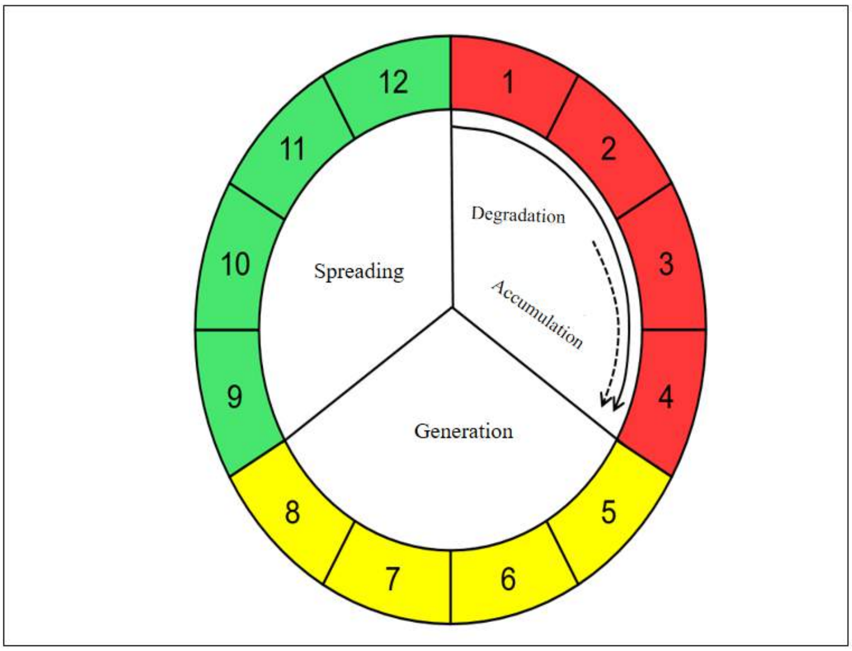

Figure 1. A year cycle of "black water" generation in the study area

It can be seen that black water in Lung Ngoc Hoang NR has the darkest color originating in the forest areas in the zone of strict protection and ecological rehabilitation (black water level 1), this is also the accumulation of black water. The field survey revealed that Lung Ngoc Hoang NR has only 6 sluice gates for water regulation. However, water is stored in the nature reserve in the dry season for the period of six months to prevent and response to potential forest fire. As a result, water is not exchanged, resulting in water with a darker color than visible to the naked eyes. At the beginning of the rainy season, the high rainfall water volume with the opening sluice gates, the black water flows into the sub-canals generating dark brown water (black water level 2). Finally, the water merged into the main canal (Hau Giang III river) - black water level 3 (Figure 2). In the main canal, the water with strong current speed, wide and deep, making the black water diluted.

The results in Table 3 showed that temperature in the rainy season was relatively stable, at NN01 and ST01, the temperature was 28.6 °C and 29 °C, respectively. The temperature does not have a large difference between the two locations because this location is located deep in the melaleuca forest with little fluctuations in flow, so the temperature is relatively stable. In addition, the amount of heat for lighting in the rainy season is low, along with aquatic plants such as algae and water hyacinths develop well. According to Phu and Ut (2006) [3], the suitable temperature for tropical species to develop is from 25 to 32 ^{o}C. In general, the average temperature between the two locations does not change much, suitable for the growth and development of fish and aquatic organisms. The pH value at position NN01 is 6.85 within the permissible limit of the A1 column standard for drinking water supply. The pH value at position ST01 is 5.59, lower than the allowable limit of QCVN 08-MT:2015/BTNMT [2], column A1 (6 - 8.5) due to being affected by the acidity of rainwater and the decomposition of vegetation. The lower pH can affect the distribution of aquatic species because pH has a great influence on the nutrition, growth and reproduction of the fish.

Figure 2. Distribution map of black water path in Lung Ngoc Hoang NR

The turbidity at NN01 was 20.8 NTU and at the ST01 was 72.5 NTU. The high turbidity could be resulting from the high concentration of TSS in water. EC at ST01 (465 µS/cm) is too high that could inhibit the absorption of nutrients providing for the growth and development of aquatic plants. EC at NN01 was lower (252 µS/cm). According to Nga and Huyen (2009) [4] each forest plot is managed differently, so the water regime is different, the content of substances in each plot is also different. Water-soluble ions such as Ca^{2+}, Mg^{2+}, SO_4^{2-}, Fe^{2+}, Fe^{3+}, Al^{3+} are abundant in acid sulfate soil water and are always changing resulting in different EC values at two sampling locations. TSS concentrations at the sampling sites ranged from 24.7 mg/L to 498.5 mg/L (Table 3). Compared with QCVN 08-MT: 2015/BTNMT [2] used for domestic water supply in column A1 (20 mg/L), both locations exceeded the permissible limit. And compared with QCVN 38: 2011/BTNMT [5] surface water quality for aquatic life (100 mg/L), the position ST01 exceeds the standard nearly 5 times, this can greatly affect aquatic life in position ST01. The reason is that position NN01 (strictly protected area) is not affected by human and poor flow, so TSS tended to settle to the bottom. In contrast, the position ST01 (ecological rehabilitation area) is affected by canoes and boats of local people increasing the disturbance resulted in TSS increases in excess of the permitted level. Suspended solids affect water quality in many ways. High concentration of TSS in water reduces the ability to transmit light in water, thus affecting the photosynthesis of aquatic plants, causing depletion of dissolved oxygen in water, affecting aquatic life.

DO concentrations was 0.28 to 0.78 mg/L (Table 3). Compared with QCVN 08-MT:2015/BTNMT, column A1 (> 6 mg/L) used for the conservation of aquatic animals, the DO at the two sampling location was extremely low. The reason is that in these two locations, the flow is poor, the water shows signs of organic pollution (black) due to the decomposition of organic matters of anaerobic organisms from dead melaleuca residues. At ST01 position, the higher dissolved oxygen concentration than the NN01 position may be due to photosynthesis of some aquatic plants and the channel is located in a well-ventilated position for better oxygen solubility. The low DO in the water could affect the growth and development of aquatic plants and animals or cause death of fish. According to Nga and Huyen (2009) [4] the low DO could increase the organic matter decomposition process and the resulting in toxic gases for example H_2S and CH_4. BOD in all locations ranged from 10.3 to 11.3 mg/L and were all higher than the permitted value by QCVN 08-MT:2015/BTNMT, column A1 (<4 mg/L).

3.2 Properties of black water in the forest area

Black water quality analysis results are presented in Table 3.

Table 3. Black water characteristics

No.	Parameters	Unit	NN01	ST01
1	Temp.	^oC	28.6	29
2	pH	-	6.85	5.59
3	Turb.	NTU	20.8	72.5
4	EC	µS/cm	252	465
5	TSS	mg/L	24.7	498.5
6	DO	mg/L	0.28	0.78
7	BOD	mg/L	11.3	10.3
8	COD	mg/L	44.48	106.56
9	H_2S	mg/L	2.55	1.98
10	NH_4^+-N	mg/L	0.368	0.483
11	NO_2^--N	mg/L	0.059	0.017
12	NO_3^--N	mg/L	0.822	0.268
13	TN	mg/L	2.6	4.0
14	PO_4^{3-}-P	mg/L	0.14	0.03
15	TP	mg/L	1.32	1.30
16	SO_4^{2-}	mg/L	28.9	158.6
17	Fe^{2+}	mg/L	0.82	10.13
18	Al^{3+}	mg/L	0.17	4.04
19	Lignin	mg/L	98.60	56.11
20	Coliform	MPN/100 mL	240	750

The reason is that the process of falling debris over the years creates a thick layer of vegetation combined with the flow regime, this layer will decompose to create dark brown water that accumulates under the forest canopy. When the rainy season comes, water overflows down the canal, causing organic pollution to the water source. In general, at the two locations NN01 and ST01 there are signs of high organic pollution because BOD exceeds the permitted threshold of the standard. The analysis results of COD concentration in surface water at the sampling locations in the rainy season are significantly different. COD values ranged from 44.48 mg/L to 106.56 mg/L. COD values analyzed at the points were higher than the permitted standard of QCVN 08-MT:2015/BTNMT [2], column A1 (10 mg/L). According to Lien et al. (2016) [6] COD in water is about 10-20 mg/L, the water environment is considered to be nutrient rich, so based on the results of COD analysis, it shows that the water environment in the study area nutritious. The ratio of COD/BOD at all sampling locations is 3.9 - 10.3. This indicates that the water is heavily polluted and that the water may contain substances that inhibit the growth of microorganisms [7].

H_2S concentration had highest value at NN01 position was 2.55 mg/L and lowest at ST01 position with 1.98 mg/L. According to Boyd (1998) [7] content of H_2S from 0.01 to 0.05 mg/L can cause death to aquatic organisms. H_2S is a toxic gas that will bind with Fe of hemoglobine or Cu of hemocyanin, causing blood cells to lose the ability to carry oxygen, leading to slow growth and low survival rate due to lack of oxygen. The concentration of H_2S suitable for shrimp growth and development must be zero. According to Khoa (2007) [8], the high concentration of H_2S can be due to the low DO concentration suitable for the growth of anaerobic microorganisms and the generation of hydrogen sulfide gas. DO concentrations at NN01 and ST01 were both low at 0.28 mg/L and

0.78 mg/L, respectively. According to Khoa (2007) [8], in the natural environment, H_2S is dissociated into H^+ and S^{2-} ions and when Fe^{2+} ions occur in the environment, FeS_2 could be formed in black. So this compound could be the main substance that combines with some other compounds to make the water turns black in the study area.

The concentration of ammonium in water ranged from 0.368 to 0.483 mg/L (Table 3). The difference is not much from NH_4^+-N concentration in the protected area and in the ecological rehabilitation zone. This may be influenced by the presence of nitrifying bacteria in the water. In addition, in the rainy season, the runoff of surface water leads to pollution sources, and the above ground layer of mud makes the ammonium concentration high. Ammonium values in both locations were higher than that regulated in QCVN 08-MT: 2015/BTNMT [2], column A1 for the protection of aquatic animals and domestic water supply (0.03 mg/L). According to to Khoa (2007) [8] NH_4^+-N in anaerobic conditions would be converted to NH_3 at the two positions NN01 and ST01. When the concentration of NH_3 in the water is higher than the concentration of NH_3 in fish blood, NH_3 in the water will diffuse into the blood, inhibiting oxygen transport, inhibiting growth and development of aquatic animals [9]. NH_3 toxicity is higher at low temperature, combined with low DO and low pH, this causes fish to die in the morning. On the other hand, NH_4^+-N is a nutrient for algae in water sources, if the light conditions are right, it will promote the photosynthesis of algae. Boyd and Green (2002) [10] classified the eutrophication level in the freshwater system for nitrogen concentration from 0.18 to 0.43 mg/L and phosphorus from 0.025 to 0.06 mg/L. The analytical results showed that NO_2^--N values in the two positions NN01 and ST01 (Table 3) were 0.059 mg/L and 0.017 mg/L, respectively. At position NN01, concentration of NO_2^--N exceeds the permitted threshold of QCVN 08-MT: 2015/BTNMT [2], column A1 while NO_2^--N, at position ST01 does not exceed the standard. According to Boyd (1998) [7] nitrite is absorbed by fish and other aquatic animals, it can combine with hemoglobine of the blood to form methemoglobine or the toxicity of NO_2^--N, commonly known as brown blood disease, which prevents prevents the combination of oxygen and hemoglobine forming oxyhemoglobine, suffocating fish. The concentration of NO_3^--N at the sampling sites ranged from 0.268 to 0.822 mg/L (Table 3). The highest concentration of NO_3^--N at NN01 was 0.822 mg/L and lowest at ST01. According to Chi (1998) [11] NO_3^--N is only stable under aerobic conditions, under anaerobic conditions, they are quickly reduced to free nitrogen and separated from water. Therefore, it is possible that the NO_3^--N concentration has been reduced to free nitrogen and separated from the water resulting in low NO_3^--N at the ST01 position. TN was the difference between the position NN01 (2.6 mg/L) and ST01 (4 mg/L) (Table 3). The results showed that the PO_4^{3-}-P concentration in water ranges from 0.03 to 0.14 mg/L. PO_4^{3-}-P at point NN01 exceeds QCVN 08-MT: 2015/BTNMT [2], column A1 (0.1 mg/L) while PO_4^{3-}-P at position ST01 does not exceed the permitted standard. PO_4^{3-}-P is a source of nutrients for plants in the water, but high levels can cause pollution that promotes eutrophication in the pond environment. TP at NN01 and ST01 were respectively 1.32 mg/L and 1.3 mg/L (Table 3). Total phosphorus exists mainly in organic phosphorus.

SO_4^{2-} at the two sampling sites NN01 and ST01 were 28.9 mg/L and 158.6 mg/L, respectively (Table 3). At position ST01, the concentration was 158.6 mg/L higher than that of NN01. The increased sulfate concentration is one of the typical indicator of acid sulfate contaminated water areas [11]. Analysis results of Fe^{2+} at the position NN01 had low value of 0.82 mg/L and the position ST01 had high Fe^{2+} (10.13 mg/L). Fe^{2+} concentrations at 2 locations all exceed the standard QCVN 08-MT: 2015/BTNMT (column A1) [2]. Similar to Fe^{2+}, Al^{3+} values at the NN01 and ST01 positions ranged from 0.17 mg/L to 4.04 mg/L (Table 3). High Fe^{2+} and Al^{3+}in water affects the development of aquatic organisms, especially aquatic plants. The analytical results showed that the concentration of lignin at sampling locations ranged from 56.11 mg/L to 98.6 mg/L. Lignin is formed by the decomposition of organic matters. The presence of lignin could be one of the causes of black water generation in the study area. Lignin concentration is inversely proportional to the DO content in water. Lignin is in contact with water, it will create a thin film on the surface of the water, which can limit oxygen diffusion into the water, making the DO decrease. Lignin has a very low toxicity to experimental fish. Coliform at NN01 was 240 MPN/100mL and at ST01 was 750 MPN/100mL, lower than the allowable standard of column A1 of 2500 MPN/100mL of QCVN 08-MT: 2015/BTNMT [2].

4. Conclusions

The study results show that black water appears in rainy months from June to October from forest areas plot 06 and plot 85 with small channels and poor flow. Black water is caused by decomposition of plant residues from fallen objects in the forest undergoing anaerobic decomposition to form compounds mainly lignin and H_2S. Black water has parameters of BOD, COD, TSS, NH_4^+-N, NO_3^--N, NO_2^--N, TN, TP, PO_4^{3-}-P, EC, TSS, BOD, COD exceeding the allowable limit of QCVN 08 - MT: 2015/BTNMT, column A1. DO is extremely low. The heavy metals of Al^{3+} and Fe^{2+} are both higher than the permissible limits. The current state of water quality can seriously affect the aquatic diversity in the reserve. The Management Board of Lung Ngoc Hoang Nature Reserve needs a long-term solution to well manage water resources to serve the local people and protect aquatic life.

References

[1] Nguyen Lan Phuong (2018). Report on results of medical waste management at Can Tho Central General Hospital in 2018.
[2] American Public Health Association, 1998. Standard Methods for the Examination of Water and Wastewater, 20th edition, Washington DC, USA 1998.
[3] Ministry of Environment and Natural Resources (MONRE). QCVN 08-MT: 2015/BTNMT National technical regulation on surface water quality, 2015.
[4] Phu, T.Q, Ut, V.N. 2006. Water quality for pond aquaculture. Can Tho University. College of Aquaculture and Fisheries. 199 pp (in Vietnamese).
[5] Bui Thi Nga and Nguyen Thi Huyen, 2009. Hydro-chemical characteristics in the protected area of Tra Su Melaleuca forest landscape. Journal of Science - Can Tho University, No. 12, pages 51 - 61.
[6] Ministry of Environment and Natural Resources (MONRE). QCVN 38:2011/BTNMT. National technical regulation on Surface Water Quality for protection of aquatic lifes
[7] Lien, N.T.K., Huy, L.Q., Oanh, D.T.H., Phu, T.Q., Ut, V.N., 2016. Water quality in mainstream and tributaries of Hau River. Can Tho University Journal of Science, 43: 68-79. (In Vietnamese).
[8] Boyd, C. E., 1998. Water quality for pond Aquaculture. Department of Fisheries and Allied Aquacultures. Auburn University, Alabama 36849 USA, 37 pp.
[9] Le Van Khoa, Nguyen Xuan Quynh and Nguyen Quoc Viet, 2007. Environmental Biological Directive. Education publisher.
[10] Le Manh Tan, 2006. Assessment of impacts on water quality in Can Gio shrimp farming area. Science and Technology Development Journal.
[11] Boyd, C.E. and Green, B.W., 2002. Water quality monitoring in shrimp farming areas: an example from Honduras, Shrimp Farming and the Environment. The World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment; Auburn: USA.
[12] Dang Kim Chi, 1999. Environmental Chemistry Textbook 1. Hanoi Science and Technology Publishing House.