

POLLUTION ASSESSMENT OF CAI SON, BA BAU, AND ONG MANH CHANNELS: A STUDY ON WATER AND SEDIMENT QUALITY IN AGRICULTURAL AREAS**Nguyen Tran Thien Khanh* ,Dương Mai Linh*, Huynh Phuc Luyen** and Vo Hua Huyen Tram*****

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ABSTRACT

The study Environmental status-quo assessment in Cai Son channel, Ba Bau channel and Ong Manh channel" was conducted to evaluate the level of pollution through the measurement of physical, biological criteria and heavy metal in water and sediment in Cai Son channel, Ba Bau channel and Ong Manh channel. The analysis of 6 water and 6 sediment samples in 3 channels shows the parameters such as dissolved oxygen in water (DO), total suspended solids content (TSS), biological oxygen demand (BOD₅), Chemical oxygen demand (COD), Ammonium, Phosphate, Coliform contents all exceed the permissible limits of QCVN 08-MT:2015/BTNMT - National technical regulation on surface water quality. The parameters of Nitrate, Vegetable oil and fat content are still within the allowed limits of the regulation. The contents of nutrients, nitrogen, and phosphorus are high. No heavy metals such as Pb, Cr, Cu are detected in all water samples, Cd is detected at 0.001 mg/l in Cai Son channel, within the permissible limits of QCVN 14:2008/BTNMT - National technical regulation on domestic wastewater. The content of As, Cd, Cr in the sediment is within the permissible limits for all type of soil according to QCVN 03:2017/BTNMT - National technical regulation on the allowable limits of heavy metals in the soils. The level WQI is at the level of serious pollution. The samples of sediment, heavy metals such as Cr, Cd, As, Fe are within the permissible limits of QCVN 43:2017/BTNMT - National technical regulation on sediment quality. Hg is not detected. The contents of Al, Mg are quite high. Sediment is rich in organic matter, high in nitrogen and phosphorus

Keywords: Remote sensing; floodplain; deposited sediment; An Giang.

INTRODUCTION

Water is crucial for fostering inclusive sustainable development since it supports human populations, maintains environmental services, and fosters economic growth (United Nations Water, 2015). Over the past one hundred years, the demand for water around the world has increased by six times and has continued to rise at a rate of roughly one percent per year (United Nations Water, 2018). The Mekong River can be considered as the largest river system supplying water to the Mekong Delta region. A part of the river system flows into An Giang province through the Hau River, in which Long Xuyen City as well as some other areas of An Giang Province receive abundant water from the main stream of the Hau River and it continues to divide. Water is stored by a system of channels or canals. However, channels in the city are currently clogged and polluted. Water of channels is usually black and smelly. Households or the passersby along these channels are always exposed to health risks due to the contaminated water. On the other hand, seriously polluted water from these watercourses flows directly out to Hau river without any treatment which will adversely affect the water quality of this river (Viet Le Hoang et al, 2017). This has led to many consequences such as negative impacts on aquatic ecosystems, low water quality for domestic, industrial, agricultural, recreational and tourism activities... Cai Son channel, Ba Bau channel and Ong Manh channel are among the typical examples of the pollution situation in Long Xuyen city. Pollution, here, has been going on for many years, it is not only reflects in the black and smelly water but contaminants also build up for a long time in the sediment. This amount of sediment is diverse in composition as well as the nature of toxic pollutants creating a potential threat to aquatic ecosystems as well as human health (Le Trong Dung et al, 2019). Therefore, the People's Committee of Long Xuyen City has planned to implement activities to improve the status of some channels in Long Xuyen City, including Cai Son channel, Ba Bau channel and Ong Manh channel. The activities will include: dredging watercourses, constructing domestic wastewater collection and treatment systems, planting trees ... "Environmental status-quo

assessment in Cai Son channel, Ba Bau channel and Ong Manh channel” was conducted to assess the initial environmental status-quo of Cai Son, Ba Bau canal and Ong Manh channels as a basis for further comparison with environmental quality in the future after applying measures to restore these ones.

Study area

Cai Son channel, Ba Bau channel and Ong Manh channel in Long Xuyen city:

- Cai Son channel with a length of $L = 1.8$ km starts from the intersection with Hau river and ends at the intersection with Tam Bot channel, located in My Long, My Xuyen and My Phuoc wards.
- Ong Manh channel with a length of $L = 1.4$ km starts from the intersection with Long Xuyen canal and ends at Km1+ 600, located in Dong Xuyen, My Hoa wards.
- Ba Bau channel with a length of $L = 1.0$ km, starts from the intersection with Long Xuyen channel and ends at Km1+00, located in Dong Xuyen ward.



Fig. 1. Map of Cai Son channel, Ba Bau channel, Ong Manh channel

Method

Locations of sampling

Water and sediment are collected at the same representative locations.

The samples consist of 6 water samples and 6 sediment samples collected at in the same phase:

- Two representative locations are chosen to collect water samples near the beginning of the channel and near the end of the channel. In particular, for each representative location, small samples were collected and then combined to form a composite sample: 1 sample/location x 2 locations/channel x 3 channels = 6 water samples (17 parameters/sample).
- Two representative locations are chosen to collect sediment samples near the beginning of the channel and near the end of the channel. In particular, for each representative location, samples were collected and then combined to form a composite sample: 1 sample/location x 2 locations/channel x 3 channels = 6 water samples (10 parameters/sample)



Fig. 2. Location for collecting water and sediment samples in Cai Son channel



Fig . 3. Location for collecting water and sediment samples in Bau Bau channel and Ong Manh channel

Methods of Sampling, Preserving and Analyzing Samples

Water sample: measuring 17 parameters of temperature, pH, DO, TSS, COD, BOD₅, NO₃ calculated by N, NH₄⁺ calculated by N, PO₄³⁻ calculated by P, Coliform. total P, total N, Pb, Cr, Cd and Cu, animal and vegetable fats and oils.

Sediment sample: measuring 10 parameters of Cr, Cd, As, Hg, Fe, Al, Mn, total Nitrogen, total Phosphorus and organic matter.

Sensory criteria: color, smell of water, sediment.

Noting some plants and animals at the locations

The method of collecting water and sediment samples complies with the following ones:

Table 1. Method of sampling

No.	Sample/ Parameter	Standard, method
1	Temperature, pH, DO	Measured at the location
2	Water sample	TCVN 6663-6:2008 (ISO 5667-6:2005)
3	Microorganism analysis sample	ISO 19458
4	Sediment sample	TCVN 6663-3:2008 (ISO 5667-3:2003)

Method of sample analysis

Method of measuring parameters at the location

Table 2. Method of measuring parameters at the location

No.	Parameter	Standard, method
1	Temperature	TCVN 4557:1988 (ISO 10523:2008)
2	pH	TCVN 6492:2010
3	DO	TCVN 7325:2004

Method of analyzing water samples in a laboratory

Table 3. Method of analyzing water samples in a laboratory

No.	Parameter	Standard, method
1	Total suspended solids (TSS) content	SMEWW 2540 D:2012
2	COD content	Hach Method 8000
3	BOD5 content (at 200C)	SMEWW 5210 D:2012
4	Ammonium content (NH_4^+) (calculated by N)	TCVN 5988:1995
5	Nitrate content (NO_3^-) (calculated by N)	SMEWW 4500- NO_3^- - E:2012
6	Content of phosphate (PO_4^{3-}) (calculated by P)	SMEWW 4500-P- E:2012
7	Total Phosphorus (calculated by P)	SMEWW 4500-P.B E:2012
8	Total Nitrogen (in N)	TCVN 6638:2000
9	Total Coliform	TCVN 6187-2:96
10	Copper (Cu) content	US.EPA. Method 200.7
11	Cadmium content (Cd)	US.EPA. Method 200.7
12	Total Chromium (Cr)	US.EPA. Method 200.7
13	Lead Content (Pb)	US.EPA. Method 200.7
14	Animal and vegetable fats and oils	TCVN 5070:1995

Table 4. Method of analyzing sediment samples in a laboratory

No.	Parameter	Standard. Method
1	Chromium content (Cr)	US.EPA. Method 200.7
2	Cadmium content (Cd)	US.EPA. Method 200.7
3	Arsenic (As) content	US.EPA. Method 200.7
4	Mercury content (Hg)	US EPA Method 3051A +US EPA Method 200.7
5	Iron content (Fe)	US.EPA. Method 200.7
6	Aluminum Content (Al)	US.EPA. Method 200.7
7	Manganese (Mn) Content	US.EPA. Method 200.7

8	Total Nitrogen	TCVN 6498:1999
9	Total Phosphorus	TCVN 8940:2011
10	Total organic matter content	TCVN 6644:2000

Application of water quality index WQI to assess water quality

Water quality index (WQI) was calculated based on Decision 879/QD-TCMT on July 1st, 2011 by the General Department of Environment on promulgating the handbook for calculating water quality index. Parameters used to calculate WQI usually include: DO, temperature, BOD₅, COD, N-NH₄, P-PO₄, TSS, turbidity, total Coliform, pH. However, because the measurement of turbidity parameters was not conducted in the research, the calculation is only applied for the other parameters.

Results and Discussion

Assessing water quality in Cai Son channel, Ba Bau channel and Ong Manh channel

Sensory assessment

Sensory assessment of water samples collected at Cai Son channel, Bau Bau channel and Ong Manh channel as follows:

- Cai Son Channel: Black, Turbid, Dreggy, Extremely smelly, The area is quite polluted in two locations.
- Ba Bau channel: Black, Turbid, Dreggy, Pretty smelly in two locations.
- Ong Manh Channel: Grey, Clean, Dreggy, Pretty smelly, The sampling area has much diluted by river water on location 1 and Black, Clean, Dreggy, Extremely smelly in location 2.



Fig. 4. Water samples

Water temperature measured at the sampling locations of Cai Son channel, Ba Bau channel and Ong Manh channel ranged from 27.8 to 31.9°C, the temperature was relatively stable, had slight fluctuation between locations near the beginning in comparison with that near the end of the channel. The temperature did not affect the aquatic life in the area. The results are consistent with the common temperature compared with that of monitoring results of river and channel environment in the province.

At the sampling locations in Cai Son channel, Ba Bau channel and Ong Manh channel. pH values ranged from 7 to 7.3 - neutral range - slight alkaline, relatively stable and had not much fluctuation between locations. They were located near the beginning and near the end of the channels. both under the permissible limits in accordance with QCVN 08-MT:2015/BTNMT - National technical regulation on surface water quality. column A1(6-8.5). The results are consistent with the results of monitoring the environment of the river, canals and channels in the province.

Dissolved oxygen contents in water (DO) at the sampling locations in Cai Son channel, Ba Bau channel and Ong Manh channel ranged 0.6 to 0.9 mg/l. The lowest value in Ong Manh channel was an average of 0.75 mg/l, both below the allowed limits according to the National Technical

Regulation on surface water quality QCVN 08- MT:2015/ BTNMT, column A1 (≥ 6 mg/l), column B2 (≥ 2 mg/l). This proves that water in these channels has been seriously polluted. The above results are consistent with that of water quality assessment of rivers, canals and channels in the area of LXC in 2012 with DO ranging 0.7 to 0.94 mg/l in Ong Manh channel and 0.7 to 1.76 mg/l in Cai Son channel. When DO in water is low, it will reduce the growth of aquatic animals. Water contains a lot of organic matter with fallen leaves. Microorganisms use oxygen to consume organic matter, causing oxygen depletion.

Total suspended solids (TSS) at the sampling locations in Cai Son channel, Ba Bau channel and Ong Manh channel were quite high, ranging 40.5 - 42 mg/l in Ong Manh, 51-59.5 mg/l in Cai Son and very high 244 - 336 mg/l in Ba Bau channel. Currently, Ba Bau channel has been very accreted and no or very little circulation; aquatic plants grow greater than that in Cai Son channel and Ong Manh channel. The results were all higher than the allowed limits in accordance with QCVN 08-MT: 2015/BTNMT - National technical regulation on surface water quality, in comparison with column A1 (20 mg/l). Particularly, Ba Bau had high TSS, exceeding column B2 (100 mg/l). If compared with QCVN 14:2008 BTNMT - National technical regulation on domestic wastewater, TSS of Cai Son channel and Ba Bau channels exceeded the permissible level, column A (50 mg/l) and column B (100 mg/l). The above results were much higher than that of river, canal and channel quality assessment of LXC in 2012 with TSS ranging 27 - 85 mg/l in Ong Manh and 14-19 mg/l in Cai Son channel. This shows that the pollution level of TSS parameters was increasing. The high contents of suspended solids in water caused poor sense for many uses; For example, this reduced the ability to transmit light through water, thus affecting the photosynthesis process in the water, depleting the oxygen layer of the water and affecting aquatic life.

Chemical oxygen demand was quite high, ranging 210-500 mg/l in Cai Son, 260- 340 mg/l in Ba Bau and 190-400 mg/l in Ong Manh channel. COD reached the highest level at the location near the end of Cai Son (500 mg/l) and near the end of Ong Manh (400 mg/l). These results exceeded the permissible limits many times higher than the National Technical Regulation on surface water quality QCVN 08-MT:2015/BTNMT, column A1 (10 mg/l). The above results were much higher than that of river, canal and channel quality assessment of LXC in 2012 with COD ranging 33-41 mg/l in Ong Manh and 27-61 mg/l in Cai Son. The results were also higher than that of the urban wastewater monitoring in 2012 with COD of sewers was 102 mg/l and 145 mg/l in Cai Son, 180 mg/l in Ba Bau and 158 mg/l in Ong Manh channel. This shows that the level of COD pollution has increased significantly for many years. due to the increase in waste channels have less circulation, reducing the ability to self-clean. Chemical oxygen demand (COD) characterizes the level of organic matter in polluted water (including biodegradable and less biodegradable). The high contents of COD in water proves that the water is rich in organic pollutants.

The biological oxygen demand was quite high, ranging 110-260 mg/l in Cai Son, 140-180 mg/l in Ba Bau and 100-210 mg/l in Ong Manh channel. BOD₅ reached the highest level near the end of Cai Son (260 mg/l). This result exceeded the permissible limits, many times higher than the national technical regulation on surface water quality QCVN 08-MT:2015/BTNMT, column A1 (4 mg/l); in comparison with QCVN 14:2008/BTNMT- National technical regulation on domestic wastewater, BOD₅ of the sampling locations in 3 channels exceeded the allowed level, column A (30 mg/l). The above results were much higher than that of river, canals and channels quality assessment of LXC in 2012 with COD ranging 10-18 mg/l in Ong Manh and 3-17 mg/l in Cai Son. The results were also higher than that of the urban wastewater monitoring in 2012 with BOD₅ of sewers was 53 mg/l and 75 mg/l in Cai Son, 96 mg/l in Ba Bau and 85 mg/l in Ong Manh channel. This shows the level of COD pollution has increased significantly for many years. Biological oxygen demand (BOD₅) reflects the amount of easily biodegradable organic matter present in the water samples. The higher the BOD value is the higher the degree of organic pollution is. Organic pollution results from that people dumping into channels and domestic wastewater from residential areas. The amount of organic humus is increasingly accumulated time by time, reducing the area and volume of the channels, obstructing the flow, reducing the circulation, limiting oxygen diffusion from the air entering

water and reducing the self-cleaning ability of the water body. In fact, organic pollution of surface water is very serious, causing negative impacts on the health of those who live in these areas.

Nitrate contents (NO_3^- calculated by N) at the sampling locations of Cai Son channel, Ba Bau channel and Ong Manh channel ranged from 0.07 to 0.08 mg/l, these values are all within the allowed limits of QCVN 08-MT:2015/BTNMT-National technical regulation on surface water quality, column A1 (2 mg/l).

Ammonium contents (NH_4^+ calculated by N) ranged 13.73-15.41 mg/l in Cai Son, 15.97-24.66 mg/l in Ba Bau and 14.01-20.73 mg/l in Ong Manh channel, exceeding the permissible limits many times in accordance with QCVN 08-MT:2015/BTNMT - National technical regulation on surface water quality, column A1 (0.3 mg/l). This shows that channel water is seriously contaminated; high ammonium facilitates the development of some aquatic plants. The above results are much higher than that of river, canal and channel quality assessment of LXC in 2012 with the contents of Ammonium (NH_4^+ calculated by N) ranging 0.96 - 1.22 mg/l in Ong Manh and 0 - 1.98 mg/l in Cai Son channel.

Phosphate contents (PO_4^{3-} calculated by P) ranged 1.21 -1.34 mg/l in Cai Son, 2.7- 2.18 mg/l in Ba Bau and 0.82-2.38 mg/l in Ong Manh channel, all exceeding the permissible limits in accordance with QCVN 08-MT:2015/BTNMT- National technical regulation on surface water quality, column A1 (0.1 mg/l). Total phosphorus contents ranged 1.61 - 1.8 mg/l in Cai Son, 2.71 - 3.41 mg/l in Ba Bau and from 1.5 to 2.8 mg/l in Ong Manh channel. Total nitrogen contents ranged 15.41 - 18.49 mg/l in Cai Son, 18.49 - 35.87 mg/l in Ba Bau and 15.97 - 25.22 mg/l in Ong Manh channel. The results show a high nitrogen content in water, similar to that in domestic wastewater at low pollution level.

Nitrogen and phosphorus contents in the channels were high because domestic wastewater flows into them. The most important sources of emission were faeces, synthetic detergents; Besides, leftovers as milk, meat, fish..., cooking utensils, food containers release a large amount of phosphorus. Meanwhile, Nitrogen is a component in food of human and animal, and a significant amount of nitrogen comes from domestic wastewater such as bathing, food washing water (vegetables, meat, fish) and septic tank water. That the concentration of nutrients rose facilitates the growth of water plants such as water hyacinth, other plants ... increasing suspended, organic matter, causing oxygen depletion in water, affecting aquatic species. Plants died and sank to the channel bottom creating sedimentary layer, gradually making watercourses shallow, causing sedimentation. The river bottom environment is the place where the oxygen concentration is very low, the bacteria decomposing in anaerobic conditions grow, resulting in the production of gases such as CH_4 . H_2S ... causing stench, making water muddy, black or dark grey.

The results show high density of Coliform at the monitoring locations in the three channels ranging $7.5 \times 10^6 - 9.3 \times 10^6$ MPN/100ml in Cai Son, $1.5 \times 10^6 - 2.4 \times 10^6$ in Ba Bau and $1.5 \times 10^6 - 2.1 \times 10^6$ MPN/100ml in Ong Manh channel, much higher than the allowed limits in comparison with QCVN 08-MT:2015/BTNMT- National technical regulation on surface water quality column A1 (2500 MPN/100 ml) and also exceeds the permissible level in comparison with QCVN 14:2008/BTNMT - National technical regulation on domestic wastewater, column A (3000 MPN/100ml). The total Coliform indicator exceeded allowed standard considerably, showing serious pollution caused by domestic wastewater and human excreta, which will be a threat to local people if they use water with a high level of pathogenic bacteria. Meanwhile, river, channel and canal water quality assessment results in the area of LXC in 2012 show that Coliform value ranged 48,000–570,000 MPN/100 ml and 7000 to 300,000 MPN/100 ml in Ong Manh and Cai Son channels, respectively. Urban wastewater quality survey results in 2012 show that the sewers of Cai Son channel has a Coliform density of 1,500,000 MPN/100 ml, 2,300,000 MPN/100 ml, that of Ba Bau is 4,300,000 MPN/100 ml and that of Ong Manh is 5,700,000 MPN/100 ml. This shows that the analysis results in this study are much higher than that in 2012, proving the pollution level is getting worse.

Animal and vegetable oils and fats parameters ranged 2.29-2.07 mg/l in Cai Son, 1.95-1.81 mg/l in Ba Bau and 0.78-1.55 mg/l in Ong Manh channel, lower than the limits compared to QCVN 14:2008/BTNMT-National technical regulation on domestic wastewater, column A (10 mg/l). Urban wastewater quality survey results in 2012 show that oils and fats contents are 0.4 mg/l and 1.1 mg/l at the sewers in Cai Son, 0.5 mg/l at the sewers in Ba Bau, and 1.1 mg/l at the sewers in Ong Manh channel. This shows that the contents of oils and fats at this time has increased in comparison to that of the previous time.

The analytical results show that no heavy metals Pb, Cr, Cu were detected in all water samples. 0.001 mg/l of Cd is detected at 2 locations in Cai Son. This content is within the permissible limit in accordance with QCVN 14:2008/BTNMT-National technical regulation on domestic wastewater, column A1 (0.005 mg/l).

Water Quality Index (WQI)

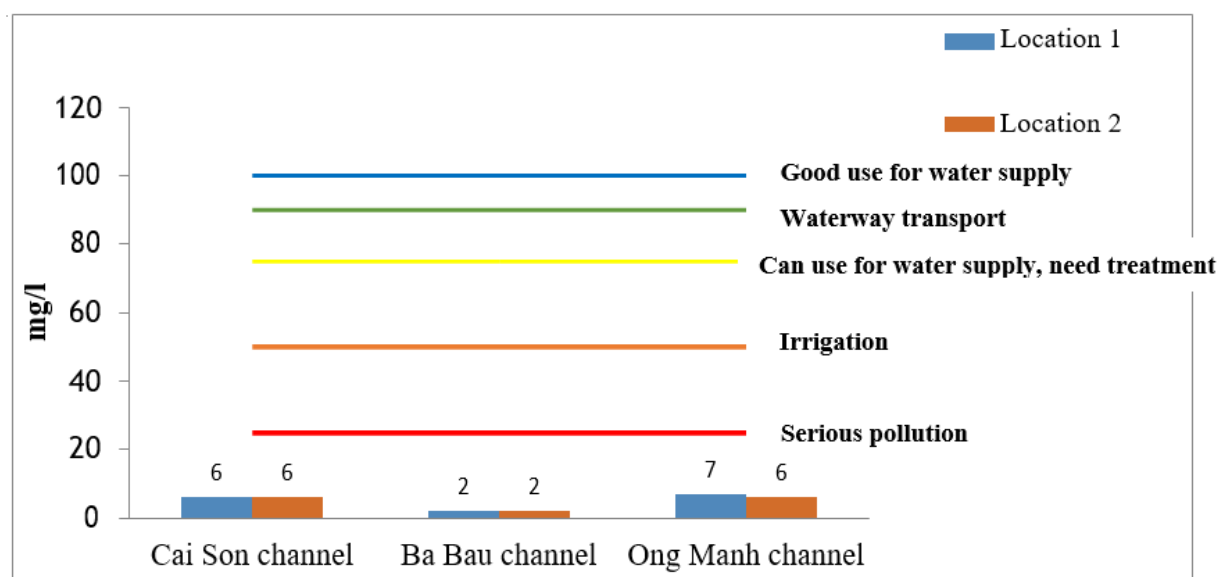


Fig. 5. Water Quality Index of Cai Son channel, Ba Bau channel, Ong Manh channel

Note: pH, TSS, DO, COD, BOD₅, Phosphate (PO_4^{3-} calculated by P), Ammonium (NH_4^+ calculated by N) and Coliform are parameters used in the calculation of WQI.

According to the results of calculating the water quality index (WQI), the water quality in Cai Son channel, Ba Bau channel and Ong Manh channel was assessed at level of serious pollution required treatment in the future, cannot be used for domestic, irrigation and water transport purposes. In particular, the most serious pollution was in Ba Bau channel because this channel was accreted, no longer circulates water in many sections, Cai Son channel was the second polluted after Ba Bau channel and Ong Manh channel somewhat less polluted than the other two channels.

This assessment is similar to the results of the assessment of water quality in rivers, channels of Long Xuyen city in 2012.

Sediment assement in Cai Son channel, Ong Manh channel, Ba Bau channel

Sensory assessment

Cai Son channel:

- Location 1: Sediment samples were sandy, black and have a strong, unpleasant odor. The area of sampling had many new rubbish and less aquatic plants and less circulation of water.
- Location 2: Sediment samples had little sand, black color and strong, unpleasant odor. The area of sampling had less rubbish and less aquatic plants and less circulation water.

Ba Bau channel:

- Location 1: Samples of sediment were little sandy, black color and strong, unpleasant odor. The area of sampling had a lot of assorted long- standing trash accumulated (plastic bags, plastic bottles, styrofoam boxes, dead plant, etc.), less aquatic plants.

- Location 2: Samples of sediment were little sandy, black color and strong, unpleasant odor. The area of sampling is the ending point, accreted, lots of organic waste. Many aquatic plants has grown and developed on the banks of the channel and in the channel.

Ong Manh channel:

- Location 1: Samples of sediment were much sandy, black and strong and unpleasant odor. The area of sampling had less rubbish, circulated water, some of aquatic plants well-developed.

- Location 2: Samples of sediment were little sandy, black color and strong, unpleasant odor. The area of sampling had a lot of organic waste, mainly plant residues, uncirculated water and well- grown aquatic plants.

Metals in sediments

The content of heavy metal - chromium (Cr) in the sediment fluctuated from 28.98 to 38.99 mg/kg in Cai Son channel, from 13.49 to 41.53 mg/kg in Ba Bau channel and from 25.98 to 29.40 mg/kg in Ong Manh channel that were in the permissible limit according to QCVN 43:2017/BTNMT-National technical regulation on sediment quality (90 mg/kg). The Cr content in the sediment samples were much lower than the limit used for all kinds of soil in QCVN 03-MT: 2015/BTNMT - National technical regulation on soil quality (limits are 150 mg/kg for agricultural land, 200 mg/kg for forestry and residential land, 250 mg/kg for industrial and commercial land).

The content of heavy metal – Arsenic (As) in the sediment fluctuated from 6.8 to 10.59 mg/kg in Cai Son channel, from 1.88 to 6.05 mg/kg in Ba Bau channel and from 7.09 to 12.17 mg/kg in Ong Manh channel that were in the permissible limit according to QCVN 43:2017/BTNMT - National technical regulation on sediment quality (17.0 mg/kg). The As content in the sediment samples were much lower than the limit used for all kind of soil in QCVN 03-MT: 2015/BTNMT - National technical regulation on soil quality (limits are 15 mg/kg for agricultural land, 20 mg/kg for forestry and residential land, 25 mg/kg for industrial and commercial land).

The content of heavy metal - cadmium (Cd) in the sediment fluctuated from 0.4 - 0.5 mg/kg in Cai Son channel, from 0 - 0.61 mg/kg in Ong Manh channel within the permissible limit according to QCVN 43:2017/BTNMT - National technical regulation on sediment quality (3.5 mg/kg). Cd was not detected at sampling locations in Ba Bau channel. The Cd content in the sediment samples were much lower than the limit used for all kind of soil in QCVN 03-MT: 2015/BTNMT - National technical regulation on soil quality (limits are 1,5 mg/kg for agricultural land, 3 mg/kg for forestry, 2 mg/kg for residential land, 10 mg/kg for industrial land and 5 mg/kg for commercial land).

The content of Iron (Fe) in the sediment fluctuated from 13,698 – 18,312 mg/kg in Cai Son channel. from 8,265 – 17,797 mg/kg m in Ba Bau channel and from 14,608 to 15,582 mg/kg in Ong Manh channel within the permissible limit according to QCVN 43:2017/BTNMT- National technical regulation on sediment quality (20,000 mg/kg).

The content of Aluminum (Al) in the sediment fluctuated from 8,323 – 15,214 mg/kg in Cai Son channel, from 3,376 – 10,738 mg/kg in Ba Bau channel and from 7,370- 9,059 mg/kg in Ong Manh channel. Al content in the sediment was unevenly distributed between the location near the beginning and the point near the end of the channel.

Al is usually the metal with the highest concentration in sediment of sewages, rivers, channels and canals. The average value of Al in conventional municipal sludge was about 728 mg/kg (Wild, 1993). The Al content in the sediment samples in this study is quite high, This parameter is not included in

QCVN 43:2017/BTNMT - National technical regulation on sediment quality.

The content of Manganese (Mn) in the sediment fluctuated from 122.08 – 126.88 mg/kg in Cai Son channel, from 74.95 – 421.06 mg/kg in Ba Bau channel and from 14.00 – 216.57 mg/kg in Ong Manh channel. This parameter is not included in QCVN 43:2017/BTNMT-National technical regulation on sediment quality. Mn content in sludge and water of urban sewage usually ranges from 32 to 9670 mg/kg with the average of 260 mg/kg (Logan, 1990). Manganese is a trace element in soil and essential for plants. The Mn content in the surface layer of some soil types in Vietnam ranges from 14.5-1192 mg/kg (Tran Cong Tau, Tran Cong Khanh, 1998). According to the scale of classification of trace elements content in soil (Le Van Van, 1975), the soil is very rich in Mn if the Mn content is > 100 mg/kg. Thus, the Mn content of sediment samples collected in the study was quite high.

According to the analytical results of all sediment samples, heavy metal of Mercury (Hg) was not detected.

The total nitrogen content (TN) in the sediment fluctuated from 4,011 to 4,557 mg/kg in Cai Son channel, from 2,350 to 2,795 mg/kg in Ba Bau channel and from 2,568 – 6,810 mg/kg in Ong Manh channel. According to the scale of Nitrogen evaluation conducted by the Vietnam Soil Science Association (2000), all sediment samples in this research were rich in nitrogen.

The total nitrogen Phosphorus (TP) in the sediment fluctuated from 4,618 to 5,358 mg/kg in Cai Son channel, from 1,057 to 1,984 mg/kg in Ba Bau channel and from 4,947 – 10,535 mg/kg in Ong Manh channel. According to the scale of Phosphorus evaluation conducted by the Vietnam Soil Science Association (2000), all sediment samples in this research were rich in Phosphorus.

The content of organic matter in the sediment fluctuated from 112.79 to 142.80 g/kg in Cai Son channel, from 60.93 to 53.72 g/kg in Ba Bau channel and from 74.20 to 200.20 g/kg mg/kg in Ong Manh channel. According to the scale of organic matter evaluation conducted by the Vietnam Soil Science Association (2000), all sediment samples in this research were rich in organic matter.

Conclusions

The results of water quality assessment at Cai Son channel, Ba Bau channel and Ong Manh channel show that the water was turbid, sedimentary, black and unpleasant odor. The water samples had temperature ranging from 27.8 to 31.9°C, pH ranging from 7-7.3; DO ranging from 0.6 to 0.9 mg/l, TSS ranging from 40.5 – 336 mg/l, COD ranging from 190 - 500 mg/l, BOD₅ ranging from 100 - 260 mg/l. NO₃⁻ (calculated by N) ranging from 0.07 to 0.08 mg/l, NH₄⁺ (calculated by N) ranging from 13.73 – 24.66 mg/l, PO₄³⁻ (calculated by P) ranging from 0.82 – 2.7 mg/l, TP ranging from 1.5 – 3.41 mg/l, TN ranging from 15.41 – 35.87 mg/l, Coliform ranging from 1.5 x 10⁶ – 9.3 x 10⁶ MPN/100ml, animal and vegetable fats and oils ranging from 0.78 – 2.29 mg/l. Parameters of DO, TSS, COD, BOD₅, NH₄⁺ (calculated by N), PO₄³⁻ (calculated by P), Coliform were exceed the permissible limits in QCVN 08-MT:2015/BTNMT-National technical regulations about surface water quality. Parameters of NO₃⁻ (calculated by N), animal and vegetable fats and oils were still under permissible limits of QCVN 08-MT: 2015/BTNMT. No heavy metal of Pb, Cr, Cu were detected in all water samples. Cd was detected at 0.001 mg/l in Cai Son channel that was under the permissible limit compared to QCVN 14:2008/BTNMT- National technical regulation on domestic wastewater. Content of nutrients as nitrogen, phosphorus in water samples was high. The WQI indicated that the water in channels was heavily polluted and could not be used for domestic, irrigation and waterway transport. In which, Ba Bau channel was the most polluted, Cai Son channel was the second most polluted and Ong Manh channel was somewhat less polluted than the other two.

Results of sediment quality assessment show that the sediment was black and had a strong, unpleasant odor. In sediment samples, Cr content fluctuated from 13.49 to 41.53 mg/kg, As fluctuated from 1.88 to 12.17 mg/kg, Cd fluctuated from 0 to 0.61 mg/kg, Fe fluctuated from 8.265 -

18.312 mg/kg, Al fluctuated from 3.376 - 15.214 mg/kg, Mg fluctuated from 141 – 412.06 mg/kg, TN fluctuated from 2.350 – 6.810 mg/kg, TP fluctuated from 1.057 - 10.535 mg/kg, organic matter fluctuated from 74.20 to 200.20 g/kg. Metals such as heavy Cr, Cd, As, Fe were in permissible limits according to QCVN 43:2017/BTNMT - National technical regulation on sediment quality. The contents of As, Cd, Cr in the sediment were lower than the permissible limits for all soil types in QCVN 03-MT:2015/BTNMT-National technical regulation on soil quality. Heavy metal - Hg was not detected. The content of Al and Mn was quite high. Sediment was rich in organic matter, high in nitrogen and phosphorus.

In many heavily polluted parts of channels, it was almost impossible to find aquatic animals. In some circulating waterways with less pollution in the channels, especially those near Hau river or Long Xuyen channel, there were many fishes in the flood season like climbing perch, snakeskin gourami, snakehead, pangasius catfish, small spot pangasius, rasbora, snail and eel... At the sampling points, many well-grown plants such as water hyacinth (popular), piper lolot, pennywort, Asiatic dailyflower, cocoyam, common reed...

Cai Son channel, Ba Bau channel and Ong Manh channel receive untreated domestic wastewater from residential areas in the basin. Besides, there are outlets from other areas of the city discharging into channels while they are accreted and stagnant for a long time so the self-clean ability of the channels is very poor. In addition, the main causes of pollution on the channels is the dumping of rubbish into the channels by some people who are low aware.

Competing Interests

Authors have declared that no competing interests exist.

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