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## Water quality at Cai river mouth and Tac river mouth, Nha Trang bay (2015–2019)

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### ABSTRACT

Deltas of large rivers, especially in arid areas, have been used in ancient times for agriculture and are densely populated. In recent decades, many river deltas have been experiencing an increasing anthropogenic impact, contamination of watersheds, and marine pollution caused by the offshore extraction of hydrocarbons. Combining of these factors determines a considerable research interest in river mouth areas. This paper presents the annual monitoring data on the water environment of the two mouths of the Cai river and Tac river, Nha Trang bay, during the period 2015–2019. Statistical data showed an increase in dissolved oxygen demand (DO), biological oxygen demand BOD<sub>5</sub>, and the concentrations of ammonia, Zn and Cu. Seasonal variation revealed that most of studied parameters' concentrations, especially nutrients, were higher in the rainy season. In contrast, the values of total suspended solids (TSS) and hydrocarbon (Cai River), and petroleum (Tac river) demonstrated a decrease. Generally, the average value of BOD<sub>5</sub>, concentrations of Cu and Pb at the Cai river mouth were lower than those at the Tac river mouth, whereas the concentration of Zn was higher. Overall, the water environment of both mouths was qualified for aquaculture and aquatic organism preservation purposes except for the case of coliform.

**Keywords:** Water quality, monitoring, Cai river mouth, Tac river mouth, Nha Trang bay.

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## INTRODUCTION

Extending from Bai Tien beach to Lo river and from the shore to Hon Dung island, Nha Trang bay is a famous tourist destination with a beautiful beach over 103 km in length and various islands. The bay receives freshwater mainly from the Cai river (in the North) and the Tac river (in the South). Cai river is the longest in Khanh Hoa province, with a length of 75 km, and its watershed area is about 2,000 km<sup>2</sup>. Separately from the Cai river, the Tac river is a smaller one located in the south of Nha Trang city, with a watershed area of 44.2 km<sup>2</sup> and a length of 14 km. Annually, the two river systems estimate 80.38 million tons/year and 0.26 million tons/year respectively of suspended matters. Previous studies on water quality monitoring and modeling of pollutants transportation from the river mouths to Nha Trang bay have shown that surface flows rich in nutrients from the continent had considerable effects on the bay's water quality, especially in the rainy season [1–3]. From 2007–2011, there was an unusual increase in the nutrient concentrations, BOD<sub>5</sub> value, and coliform density in both river mouths [4]. Especially in the Tac river mouth DO was always below 5 mg/L; and there was also the contamination of HC and coliform. Water quality assessment and management have played an essential role in sustainable economic development to minimize these effects. Therefore, environmental monitoring programs in Khanh Hoa province have been well developed and improved. Since 2011, which the Nha Trang bay Management Committee had held, Cai river mouth water quality has been examined twice a year (dry and rainy season). In addition, in 2015, the Tac river mouth was added as an important monitoring station of the Khanh Hoa province

monitoring network with a high sampling frequency (one time per month). These programs have provided valuable data for the environmental management and preservation of Nha Trang bay.

This paper presents the annual monitoring data on the water environment of the two mouths of the Cai river and Tac river, Nha Trang bay during the period 2015–2019. It has the potential to be used by environmental managers and policymakers to improve the management of the river to contribute to sustainable development of the province.

## MATERIALS AND STUDY METHODS

The analytical data used for this study are results of sampling programs in the Cai and Tac rivers undertaken between 2015 and 2019. This time period was selected due to the abundant availability of sample data. Water samples were collected at the Cai river mouth (station SC, at the surface and bottom) and the Tac river mouth (station ST, at the surface) (Figure 1). Samples sampling and analysis methods are summarized in Table 1.

Data were processed using Microsoft Excel and Minitab software. Water quality was assessed using National technical regulation on marine water quality (QCVN10:2015/BTNMT) for pH, total suspended solids (TSS), dissolved oxygen (DO), ammonia, phosphate, coliform, hydrocarbon, and heavy metals (Zn, Cu, Pb, Fe); Water quality - Standard for quality of coastal water (TVVN 5943:1995/BTNMT) for biological oxygen demand (BOD<sub>5</sub>); ASEAN Marine Water Quality Management Guidelines and Monitoring Manual for nitrite, nitrate - applied for aquatic organisms preservation purpose [5–7].

Table 1. Sampling and analysis methods

Station	Date	Parameters	Methods
SC (109.2033170; 12.26016703)	June and November 2015, 2016, 2018, 2019	pH, DO, BOD <sub>5</sub> , TSS, NH <sub>3,4</sub> -N, NO <sub>2</sub> -N, NO <sub>3</sub> -N, PO <sub>4</sub> -P, SiO <sub>3</sub> -Si, Zn, Pb, Cu, Fe, HC, coliform, Vibrio	Standard Methods for The Analysis of Water and Waste Water [8]
ST (109.2105496; 12.18959921)	Monthly, 2015–2019	pH, TSS, DO, BOD <sub>5</sub> , COD, NH <sub>3,4</sub> -N, Zn, Pb, Cu, As, dầu mỡ, coliform	

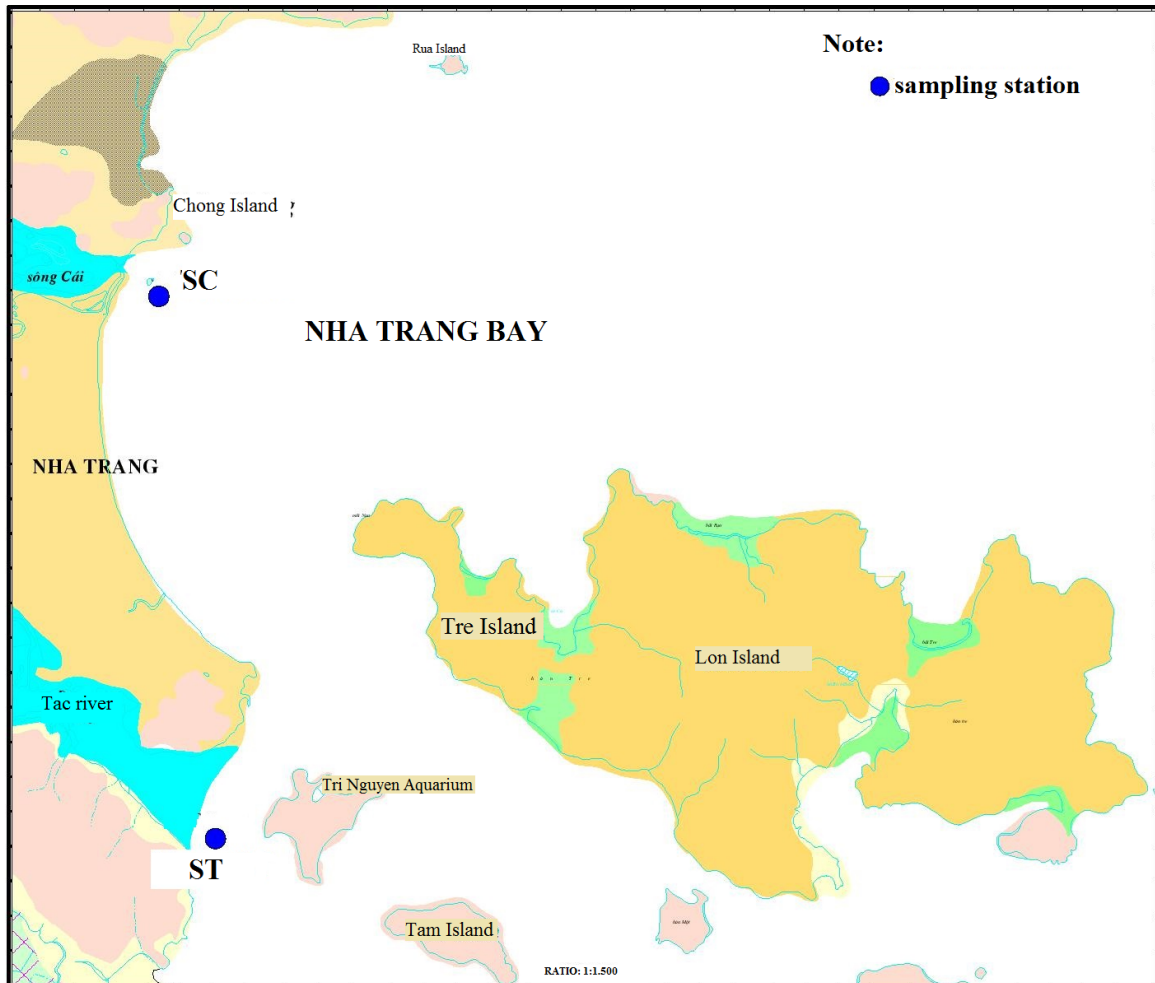


Figure 1. Sampling stations

## RESULTS

### Assessment of water quality in Cai river mouth

Monitoring data in dry and rainy seasons at the Cai river mouth showed that values of TSS, nutrients, Fe, and coliform were higher in the rainy season than those of dry season. Specifically, in the rainy season, the average concentrations of TSS, ammonia, silicate, and Fe were: TSS: 24 mg/L; ammonia: 20.4  $\mu\text{gN/L}$ ; nitrite: 8.8  $\mu\text{gN/L}$ ; nitrate: 81.6  $\mu\text{gN/L}$ ; phosphate: 12.6  $\mu\text{gP/L}$ ; silicate: 2,070  $\mu\text{gSi/L}$ ; Fe: 405  $\mu\text{g/L}$  - increased from 1.1–4.6 times as compared with those measured in the dry season. Similarly, coliform density also rose significantly from 14,000 MPN/100 mL in dry months to approximately 60,000 MPN/100 mL

in rainy months. In contrast, DO, BOD<sub>5</sub>, and HC values decreased during the rainy season. There was no apparent seasonal pH variation, some heavy metals (Zn, Cu, Pb) and vibrio. Generally, although there was an increase of studied parameters during the rainy season, the environmental quality of Cai river remained good during this period, and the values of those parameters were lower than the criteria given in the regulations mentioned above (Table 2).

### Assessment of water quality in Tac river mouth

Seasonal values/concentrations of studied parameters in the Tac river mouth during the period 2015–2019 are presented in Table 3. Comparably to Cai river mouth, the

concentrations of TSS, ammonia and coliform density in this area also rose in the rainy season, especially the case of ammonia, and coliform density, which were 23 µgN/L and 12,432 MPN/100 mL, and were five times and 90 times higher respectively in comparison with those in the dry season. Regarding heavy metals, the presence of Zn, Cu, and As also increased when there were rains. In contrast, values of pH, DO decreased in the same period.

Whereas, COD, Pb, and petroleum did not show a clear seasonal variation. In other words, the environmental quality of the Cai river also remained good from 2015–2019; the values of studied parameters were lower than the criteria given in the regulations as mentioned above, except for the case of coliform in 2015: the average value of coliform density in this year was 27,422 MPN/100 mL, and was 227 times higher than the criteria (1,000 MPN/100 mL).

Table 2. Statistical values of environmental parameters at Cai river mouth station in dry and rainy season (2015–2019)

Parameters	Dry season				Rainy season				
	n	Average	Min.	Max.	n	Average	Min.	Max.	Criteria
pH	16	7.95	7.66	8.18	16	7.95	7.52	8.28	6.5–8.5
TSS (mg/L)	16	5.2	1.1	10.9	16	24.1	4.9	44.0	50
DO (mg/L)	16	6.38	5.20	7.32	16	5.53	4.56	6.14	≥ 5
BOD <sub>5</sub> (mg/L)	16	2.10	1.09	3.64	16	1.75	0.82	3.91	4
NH <sub>3,4</sub> -N (µg/L)	16	11.0	0.0	30.6	16	20.4	1.0	54.9	100
NO <sub>2</sub> -N (µg/L)	16	8.0	2.5	19.2	16	8.8	1.9	22.1	55
NO <sub>3</sub> -N (µg/L)	16	38.7	31.6	46.0	16	81.6	60.0	140.0	60
PO <sub>4</sub> -P (µg/L)	16	10.3	2.6	17.8	16	12.6	5.1	19.5	200
SiO <sub>3</sub> -Si (µg/L)	16	1,093	109	3612	16	2,070	270	4,095	-
Zn (µg/L)	16	8.50	3.00	12.70	16	8.48	2.27	13.70	500
Cu (µg/L)	16	2.67	1.10	3.50	16	2.73	1.10	4.30	200
Pb (µg/L)	16	2.59	1.40	3.90	16	2.61	1.31	3.70	50
Fe (µg/L)	16	253	114	710	16	405	129	849	500
HC (µg/L)	16	506	368	625	16	473	376	580	500
Coliform (MPN/100 mL)	16	15,960	0	110,000	16	61,666	36	460,000	1,000
Vibrio (TB/100 mL)	16	20,401	3	55,600	16	24,938	100	172,700	

Table 3. Statistical values of environmental parameters at Cai river mouth station in dry and rainy season (2015–2019)

Parameters	Dry season				Rainy season				
	n	Average	Min.	Max.	n	Average	Min.	Max.	Criteria
pH	40	8.12	7.80	8.30	20	8.08	7.80	8.40	6.5–8.5
TSS (mg/L)	40	10.5	2.0	35.0	20	16.6	5.0	27.0	50
DO (mg/L)	40	6.09	5.20	7.20	20	5.81	4.90	6.50	≥ 5
BOD <sub>5</sub> (mg/L)	40	2.73	1.00	4.00	20	2.76	1.00	6.00	4
COD (mg/L)	40	7.88	4.60	13.0	20	7.36	4.60	10.0	-
NH <sub>3,4</sub> -N (µg/L)	40	4.9	0	23.4	20	23.1	7.0	37.0	100
Zn (µg/L)	40	3.84	1.00	9.20	20	5.18	1.10	13.00	500
Cu (µg/L)	40	2.92	0.50	6.80	20	3.56	2.30	7.40	200
Pb (µg/L)	40	4.13	1.80	8.40	20	4.28	1.50	7.20	50
As (µg/L)	40	4.90	1.40	16.00	20	5.37	2.20	7.80	20
Petroleum (µg/L)	40	281	200	400	20	255	200	400	500
Coliform (MPN/100 mL)	40	136	0	2,160	20	12432	0	240,000	1,000

In general, in both of the river mouths, the values of pH and DO were quite similar, varying from 7.8–8.2 (pH) and from 5.3–6.3 mg/L (DO). In the Tac river mouth, values of BOD<sub>5</sub>, contents of Cu, and Pb were usually higher than those recorded in the Cai river mouth. In rainy season, most of the studied parameters showed a common trend of increase in values or concentrations, which implied an effect of surface flow from the continent. The main source of wastewater in the area of the Tac river mouth was from human activities, industry, and aquaculture, whereas in the Cai river mouth area, apart from tourism and industry, trade villages and pig farms were also rapidly developing; however, there were no wastewater treatment systems installed. Thus wastewater was directly released into the river. Previous research showed that wastewater from those sources was rich in nutrients and organic matters, high BOD<sub>5</sub>, TSS values and coliform density [9]; this could be the factor that led to the increase in the value of BOD<sub>5</sub>, TSS, nutrients, and coliform in river water. Moreover, the coliform density in the Cai river mouth was five times higher than that in the Tac river mouth during the rainy season, which might indicate that human activities in the Cai river watershed (population: 546,124 people) had more noticeable effect on the water quality in comparison with Tac river watershed (population: 99,768 people).

#### Time variation of water quality in the Cai and Tac rivers mouths (2015–2019)

##### *Cai river mouth*

Table 4 presents the time variation of water quality in the Cai river mouth from 2015–2019. The data showed that, during this period, TSS values tended to decrease, but not much, whereas pH and BOD<sub>5</sub> values rose. From 2015–2018, the maximum value of BOD<sub>5</sub> was 1.6 mg/L, but in 2019 it raised to more than 3.0 mg/L (criteria, QCVN). In addition, concentrations of ammonia and silicate also clearly surged. Regarding heavy metals, Zn, Cu, and Pb were the elements that had an increase in their contents, especially Zn. In 2019, the average content of Zn was 10.45 µg/L, which was about four times higher compared to that in 2015 (2.58 µg/L).

Table 4. Average values of the environmental parameters in Cai river mouth (2015–2019)

Parameters	2015	2016	2018	2019
pH	7.86	7.71	8.10	8.13
TSS (mg/L)	15.3	23.8	3.0	5.9
DO (mg/L)	1.55	1.12	1.62	3.40
BOD <sub>5</sub> (mg/L)	6.07	5.86	6.55	5.35
NH <sub>3,4</sub> -N (µg/L)	4.8	19.2	21.4	18.8
NO <sub>2</sub> -N (µg/L)	5.0	16.9	7.1	4.9
NO <sub>3</sub> -N (µg/L)	49.2	71.8	41.5	58.3
PO <sub>4</sub> -P (µg/L)	8.6	16.0	15.2	6.0
SiO <sub>3</sub> -Si (µg/L)	891	1,437	2,099	1,898
Zn (µg/L)	2.58	9.13	10.33	10.45
Cu (µg/L)	1.23	3.15	2.75	3.30
Pb (µg/L)	1.53	2.60	3.05	2.95
Fe (µg/L)	285	371	463	144
HC (µg/L)	475	538	603	396
Coliform (MPN/100 mL)	1,677	6,523	142,756	726
Vibrio (TB/100 mL)	5,400	6,975	67,400	3,401

Overall, a 4-year record on environmental parameters revealed that ammonia, heavy metals, vibrio and coliform dramatically surged in 2018. In 2019 the water quality was much improved; however, the value of BOD<sub>5</sub> continued to increase, which remained a concern.

##### *Tac river mouth*

Statistical values of studied environmental parameters regarding water quality in the Tac river mouth in 2015–2019 were presented in Table 5. The data revealed that in this period, there was an increase in BOD<sub>5</sub> values and ammonia concentrations, especially in 2019, when all the monthly recorded values of BOD<sub>5</sub> were higher than 3 mg/L (criteria, QCVN), and ammonia concentration also rose from 7.9 µgN/L (2015) to 13.5 µgN/L. Similarly, Cu and Zn showed an increase in their contents. However, coliform contamination in this area improved in 2019: coliform density decreased 9,140 times and was lower than the threshold limit.

Table 5. Average values of the environmental parameters in Cai river mouth (2015–2019)

Parameters	2015	2016	2017	2018	2019
pH	8.20	8.10	8.09	8.08	8.10
TSS (mg/L)	12.9	20.1	15.7	12.8	11.9
DO (mg/L)	5.96	5.77	6.07	6.27	5.90
BOD <sub>5</sub> (mg/L)	2.83	2.08	3.25	2.07	3.48
COD (mg/L)	10.67	6.36	7.22	7.38	6.92
NH <sub>3,4</sub> -N (µg/L)	7.93	9.80	10.10	11.98	13.45
Zn (µg/L)	3.10	3.40	5.00	7.40	2.60
Cu (µg/L)	2.25	2.38	2.47	3.59	4.97
Pb (µg/L)	4.08	5.41	3.73	3.40	4.28
As (µg/L)	4.70	5.80	5.90	3.80	5.20
Petroleum (µg/L)	300	315	237	250	250
Coliform (MPN/100 mL)	27,422	76	379	161	3

## CONCLUSION

The water quality monitoring data in the Cai and Tac rivers mouths from 2015–2019 showed that some environmental parameters (TSS, ammonia, coliform) had clear seasonal variation. Their values/concentrations increased in the rainy season, which implied that surface flow carrying waste from land could affect the quality of the river water and thus affect the water quality in the Nha Trang bay.

Overall, during the period from 2015–2019, values of BOD<sub>5</sub>, ammonia, Cu, and Zn tended to increase over time, especially in the Tac river mouth, whereas the concentration of Pb specifically rose in the Cai river mouth. However, the water quality of both studied river mouths remained good; all of the environmental parameters were qualified for aquaculture and aquatic organism preservation purposes except for the case of coliform.

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