

## Assessment of coastal water quality of Ninh Binh province

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### Abstract

This paper presents the results of investigation on water quality in Ninh Binh coastal area in 2015. The results show that the risk quotient of water quality of the area was 0.34, indicating the water was safe for aquatic life. However, for individual water quality parameter, the coastal water of Ninh Binh was contaminated by TSS, ammonium and arsenic; water faced the risk of deficiency of dissolved oxygen. The remaining water quality parameters (nitrite, phosphate, cyanide, oil and grease, coliform, Cu, Pb, Zn, Cd, Hg and organochlorinated pesticides) are safe for aquatic life. As spatial distribution, the concentration of pollutants in water is lower at depth > 15 m. In the rainy season, the water quality tends to decrease compared to the dry season.

**Keywords:** Water quality, risk quotient, limitation value, eutrophication.

## INTRODUCTION

Ninh Binh is a province located in the south of the Red River Delta, having a coastline of over 15 km with thousand hectares of mudflats. Ninh Binh coastal zone extends over the area of 4 communes of Kim Son district, including Kim Trung, Kim Hai, Kim Dong, Kim Tan with an area of about 6,000 ha, accounting for 4.2% of the province's natural area. Compared to other coastal provinces of Vietnam, the coastline of Ninh Binh is short. The river system in Ninh Binh includes Day, Hoang Long, Boi, An, Vac, Lang and Van Sang rivers. Total length of river system is 496 km, widely distributed throughout the province. The average density of rivers and streams is 0.5 km/km<sup>2</sup>, the rivers often flow in the Northwest - southeast direction into the East Sea (according to Ninh Binh Provincial Portal). The tidal regime in Ninh Binh is a diurnal tide, besides there is a case of semi-diurnal tide and complex tide. The tide of Ninh Binh is quite weak, the average tidal amplitude is about 150–180 cm, the largest is 270 cm and the smallest is 2–5 cm (Ninh Binh Radio and Television Portal).

Ninh Binh coastal area together with wetlands of Thai Thuy and Tien Hai districts (Thai Binh province); Giao Thuy, Hai Hau and Nghia Hung districts (Nam Dinh province) has been recognized by UNESCO as the Red River Delta Biosphere Reserve of the world since 2004 (According to the Survey Report on Perceptions and Needs of Related Parties for Management and Development of the Red River Delta Biosphere Reserve, MAB & MCD, 2010). So far, there are almost no publications about coastal water quality of Ninh Binh province. Therefore, this paper presents the results of investigation on marine water quality in Ninh Binh coastal area in order to help environmental managers get a comprehensive picture of environmental quality in the coastal area of Ninh Binh and to contribute to protection of water quality of Red River Delta Biosphere Reserve.

## MATERIALS AND METHODS

### Sampling and sample preservation

The surface and bottom seawater samples are collected in the neap tide period in two

seasons: Dry season (March 2015) and rainy season (July 2015), the tide height is 2.5 m at the highest and 1.2 m at the lowest. There were 13 sampling stations distributed on 3 transects to a depth of 15 m, 1 fixed station of 24 hours located near Cua Day (collecting sample every 6 h). Each transect was arranged with 4–5 stations corresponding to depths: < 6 m (stations MR1, MR2, MR7, MR8, MR9, MR10 and MR11), 10 m (stations MR3, MR6 and MR12) and 15 m (stations MR4, MR5, MR13). In addition, there were 3 stations in tidal flat as BT1, BT2 and BT3. The location of sampling stations is shown in fig. 1.

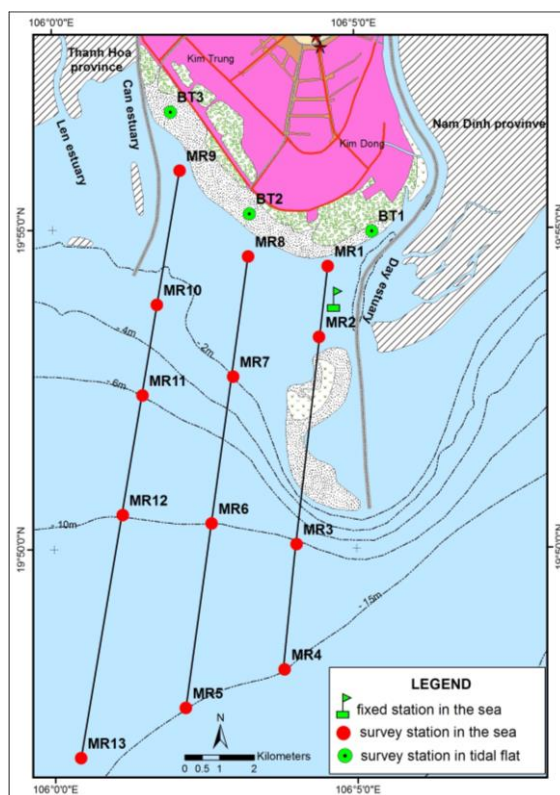


Fig. 1. The sampling stations for marine water quality of Ninh Binh province

The method of seawater sampling complied with TCVN 5998-1995 (ISO 5667-9: 1992) - Water quality - Sampling - Guidance on seawater sampling [1]. Preservation of seawater samples complied with TCVN 5993: 1995 (ISO 5667-3: 1985) - Water quality - Sampling - Instructions for preservation and handling of

samples [2]. The parameters of temperature, pH, DO, salinity, turbidity were measured directly in situ by the WQC-22A meter (TOA, Japan). Other water quality parameters (BOD<sub>5</sub>, COD, inorganic dissolved nutrients of nitrogen and phosphorus, total suspended solids, oil and grease, chlorophyll a, coliform, cyanide, heavy metals (Cu, Pb, Zn, Cd, Hg, As), organochlorinated pesticides were collected and stored at 4°C until analysis.

### Analytical methods

Analysis of water quality parameters following the published Vietnamese Standards and US standard documents [3]. Biochemical oxygen demand (BOD<sub>5</sub>) was determined by undiluted method, incubated at 20°C. Chemical oxygen demand (COD) was determined by Potassium Permanganate (KMnO<sub>4</sub>) method in alkaline environment. Total suspended solids were determined by method of filtration - drying and weighing. The oil and grease in the water were determined by colorimetric method after extracted with n-hexane. Nutrients: phosphate (PO<sub>4</sub><sup>3-</sup>), nitrite (NO<sub>2</sub><sup>-</sup>), ammonium (NH<sub>3</sub> + NH<sub>4</sub><sup>+</sup>), total nitrogen, total phosphorus were determined by colorimetric method. Heavy metals in water (Cu, Pb, Cd, Zn, Hg, As) were determined on atomic absorption spectrophotometer (AAS). Organochlorinated pesticides including lindane, aldrin, dieldrin, endrin, 4,4'-DDD, 4,4'-DDE, 4,4'- were determined by gas chromatography method with Electronic Capture Detector (ECD).

Cyanide was determined by colorimetric method using pyridine/barbituric reagent. Chlorophyll a was determined by spectrophotometric method. Coliform density was determined by filter membrane method in lauryl sulfate medium at 37°C.

### Method of evaluating water quality

To assess the quality of water in Ninh Binh waters, use National Technical Regulation on Marine water quality QCVN 10-MT: 2015/BTNMT for protection of aquaculture and aquatic life [4]. In addition, use criteria of ASEAN [5] and Australia [6] for water quality parameters that are not specified in National Technical Regulation. Besides, using the risk quotient RQ - the ratio of the amount of pollutants in water divided by regulated limitation value - for assessment of water quality. When RQ < 0.75: The water is not contaminated, 0.75 < RQ < 1: Water is at risk of contamination and RQ > 1: Water is contaminated [7]. As for DO, the RQ value of DO is calculated by dividing the regulated limitation value by the measured value.

## RESULTS AND DISCUSSION

### Physical and hydrochemical factors in coastal waters in Ninh Binh province

Survey results of physical and hydrochemical factors in the water of Ninh Binh coastal area in 2015 are presented in table 1 and fig. 2.

Table 1. Physical and hydrochemical factors in the coastal water of Ninh Binh province in 2015

Parameters	Dry season		Rainy season		Yearly aver. value	Limitation QCVN 10/2015
	Range values	Average value	Range values	Average value		
Temperature (°C)	18.9–21.2	19.7	29.0–31.0	30.4	25.0	NR
pH	6.77–7.65	7.43	7.2–8.1	7.86	7.65	6.5–8.5
Salinity (‰)	11–28	22.3	6–28	18.1	20.2	NR
Turbidity, (NTU)	22–150	51	7–224	64	58	NR
TSS (mg/l)	25.0–210.0	68.0	23.5–197.7	78.7	73.0	50

Note: NR: Not regulated.

### Temperature

In the surveys in March and July 2015, the temperature of seawater in Ninh Binh province was lowest of 18.9°C in March and was highest

of 31°C in July. Thus, in the hot summer months, the increase of temperature in seawater of Ninh Binh is likely to affect the life of marine organisms.

**pH value**

In Ninh Binh waters, the pH ranged from 6.77 to 8.05, the annual average value was 7.65. In general, the pH of water was from neutral to weak alkaline. The pH value was low at the areas below 6 m depth due to the influence of the river water mass with lower pH. The further away from the coast, the higher and more stable pH of seawater because of the

dominance of seawater mass. The increase in pH value during the rainy season was also related to strong photosynthetic reactions in the summer [8]. Compared with the limitation values regulated in QCVN 10-MT: 2015/BTNMT [4] (pH from 6.5–8.5), Ninh Binh waters have pH values within the limitation (fig. 2).

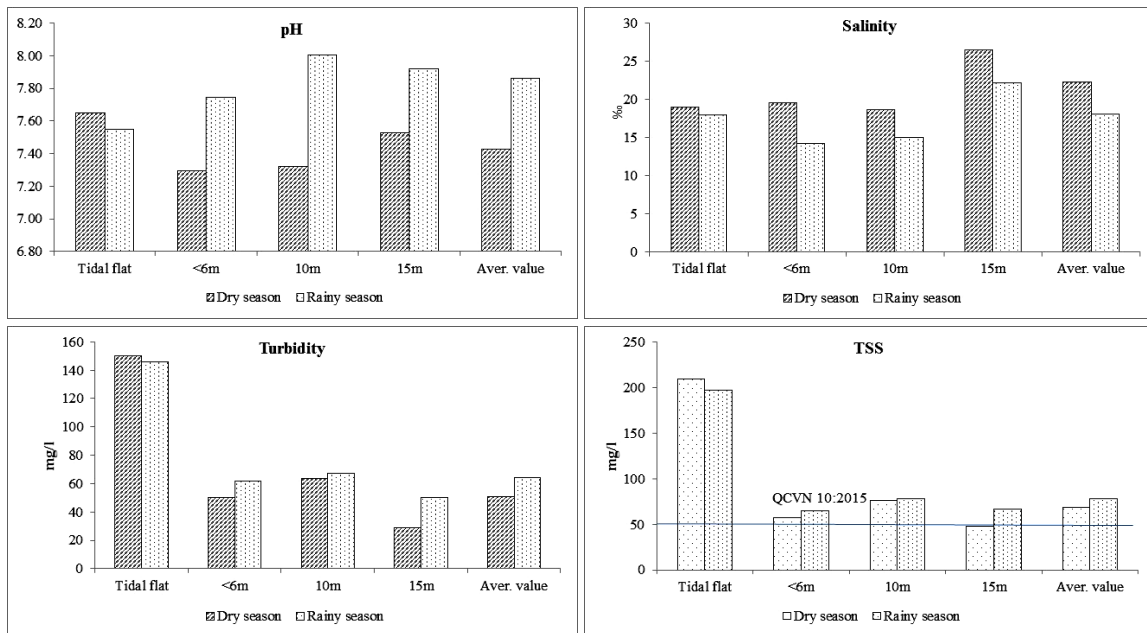


Fig. 2. Distribution of some physical and hydrochemical factors in seawater of Ninh Binh in 2015

**Salinity**

In the survey in March 2015, salinity of seawater ranged from 11–28‰, average value of 22.3‰. At the 15 m depth, the salinity of water was highest. In estuarine areas, the salinity was lowest, even lower than in the tidal flat areas. In the southern coast area (transects II and III), the salinity of water was higher than that in the northern area. In the rainy season (July 2015), salinity ranged from 6–28‰, average value of 18.1‰. In general, the water of Ninh Binh has salinity from highly brackish to saline through two surveys in 2015.

**Turbidity**

Turbidity of seawater of Ninh Binh province ranged from 7–224 mg/l, yearly average value was 58 mg/l. At tidal flats, turbidity of water was about 146–150 mg/l. The

high turbidity was distributed in areas with a depth of about 10 m, then gradually decreased offshore (fig. 2). The difference in turbidity between the surface and bottom water layers was quite high, up to 154 mg/l in the rainy season, in which the bottom water layer had a higher turbidity. Because of many estuaries, Ninh Binh seawater turbidity was quite high, obstructing photosynthesis process of phytoplankton and unfavorable for growth of coral reef.

**Concentration of total suspended solids (TSS)**

TSS concentration in seawater of Ninh Binh coastal area ranged from 23.5 mg/l to 210.0 mg/l, the average value of 73.0 mg/l. TSS concentration in water of tidal flat was about 2–3 times higher than that of under-tide area. The TSS concentration in water was

higher at the bottom layer. The TSS value in water in rainy season was higher than that in dry season from 1 times to 1.3 times. Compared to limitation value regulated in QCVN 10-MT: 2015/BTNMT (50 mg/l) for coastal water, 64% of samples show polluted by TSS during both rainy and dry seasons. This indicates that source of TSS from land is quite

high and this affects the quality of seawater in Ninh Binh coastal area.

### Marine water quality parameters in coastal area of Ninh Binh

The analytical results of organic substances consuming dissolved oxygen and nutrients in the seawater of Ninh Binh are presented in table 2.

Table 2. Marine water quality parameters in coastal area of Ninh Binh in 2015

Parameters	Dry season		Rainy season		Yearly average value	Limitation value (QCVN 10/2015)
	Range values	Average value	Range values	Average value		
DO (mg/l)	5.4–8.0	6.1	5.2–8.4	6.6	6.3	≥ 5
BOD <sub>5</sub> (mg/l)	1.89–3.65	2.37	2.21–4.72	3.05	2.71	NR
COD (mg/l)	3.06–5.74	3.70	3.75–7.81	4.73	4.21	NR
N-NO <sub>2</sub> <sup>-</sup> (µg/l)	12.10–24.26	15.78	13.90–25.85	18.22	17.00	NR
N-NO <sub>3</sub> <sup>-</sup> (µg/l)	40.8–145.8	85.44	80.0–208.5	131.89	108.66	NR
N-NH <sub>4</sub> <sup>+</sup> (µg/l)	55.8–149	86.10	74.1–191.2	104.54	95.32	100
Total N (mg/l)	0.75–3.15	1.29	1.48–5.35	1.95	1.62	NR
P-PO <sub>4</sub> <sup>3-</sup> (µg/l)	17.87–48.38	25.64	19.02–50.28	27.74	26.69	200
Total P (mg/l)	0.06–0.16	0.10	0.08–0.24	0.12	0.11	NR
Chlorophyll a (µg/l)	5.18–11.32	8.24	6.02–15.02	8.91	8.57	NR

Note: NR: Not regulated.

### Organic substances consuming dissolved oxygen

#### Dissolved oxygen (DO)

In the seawater of Ninh Binh coastal area, concentration of dissolved oxygen ranged from 5.2 mg/l to 8.4 mg/l, the average value was 6.3 mg/l, the water was not deficient in dissolved oxygen. The difference in dissolved oxygen concentration in water between surface-bottom layers was quite high, even up to 2.63 mg/l, in which DO concentration in bottom water layer was lower than that in surface one. The decline in DO concentration at the bottom layer is related to the turbidity of the water. Due to high turbidity in bottom water layer, it prevents the photosynthesis of phytoplankton there. In the tidal flat areas, the dissolved oxygen concentration was higher, especially in the dry season (fig. 3) because there was an inland-sea interaction leading to the big disturbance and increasing the dissolved oxygen content in water. In the rainy season, DO value in water was higher than that in dry season, especially in the nearshore areas. The further away from the shore, the lower

difference of DO content in seasons (fig. 3). Compared with limitation value regulated in QCVN 10-MT: 2015/BTNMT (> 5 mg/l), Ninh Binh coastal waters had no signs of dissolved oxygen deficiency at the time of survey.

#### Biochemical oxygen demand (BOD<sub>5</sub>)

BOD<sub>5</sub> value in Ninh Binh coastal water in 2015 was in the range of 1.89 mg/l to 4.72 mg/l, an average value of 2.37 mg/l in dry season and 3.05 mg/l in rainy season. The value of BOD<sub>5</sub> in water was high in the tidal flat areas, then gradually decreased from nearshore to offshore (fig. 3). In surface water layer, biochemical oxygen demand in water tended to be higher than that in the bottom layer, but the difference was small. At the fixed station, the average BOD<sub>5</sub> value was 2.77 mg/l in the dry season and 3.91 mg/l in the rainy season. Thus, in the rainy season, the demand for biochemical oxygen in the seawater in Ninh Binh was 1.3–1.4 times higher than that in the dry season. The demand for biochemical oxygen in coastal water of Ninh Binh was quite high compared to coastal water of Thanh Hoa (average value of

1.02 mg/l in the rainy season and 0.90 mg/l in the dry season) (According to project “Building database of marine resource and

environment of Thanh Hoa province” - Tran Dinh Lan et al., (2014)).

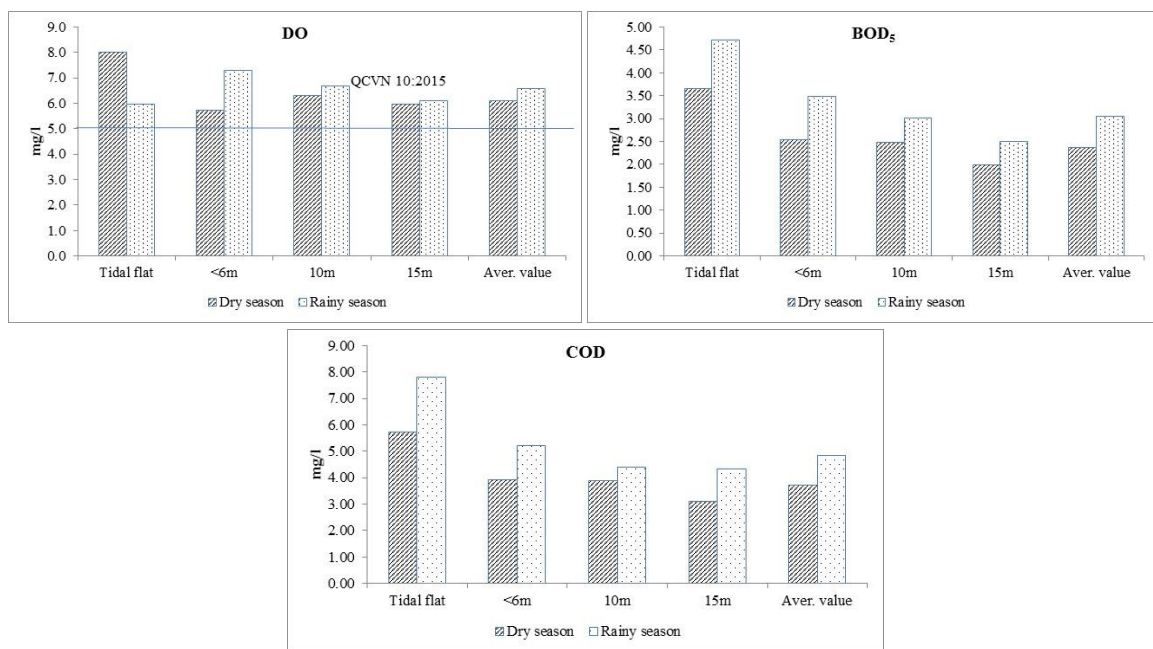


Fig. 3. Distribution of dissolved oxygen concentration and values of BOD<sub>5</sub> and COD in Ninh Binh coastal water in 2015

### Chemical oxygen demand (COD)

Chemical oxygen demand in coastal water of Ninh Binh in 2015 tended to slightly decrease from nearshore to offshore, the value ranged from 3.06 mg/l to 7.81 mg/l, the average value was 4.21 mg/l. Vietnam does not regulate limitation value for COD parameter in coastal seawater. In the rainy season, the demand for chemical oxygen in seawater increased higher than that in the dry season about 1–1.6 times. In a day, at Cua Day fixed station, the demand for chemical oxygen changed little in the dry season, but there was a big difference in the rainy season, the highest difference between the samplings was 1.15 mg/l.

In general, the coastal water of Ninh Binh has a high demand of chemical oxygen compared to other sea areas such as Thanh Hoa province and Hai Phong city. In Thanh Hoa coastal area, the average value of COD in seawater during the survey in 2011–2012 was 1.69 mg/l (According to Tran Dinh Lan et al., (2014) in project “Building database of marine

resource and environment of Thanh Hoa province”). In coastal water of Hai Phong city, the average value of COD in seawater during the survey in 2013–2014 was 2.67 mg/l (According to Luu Van Dieu et al., (2015) in project “Assessment of environmental carrying capacity of some coastal typical water bodies in Vietnam in order to serve the sustainable development”).

### Nutrient factors in seawater

#### Nitrite ( $N-NO_2^-$ )

The concentration of nitrite in coastal water of Ninh Binh ranged from 12.10  $\mu\text{g/l}$  to 25.85  $\mu\text{g/l}$ , the average value was 15.78  $\mu\text{g/l}$  in dry season and 18.22  $\mu\text{g/l}$  in rainy season. Vietnam does not regulate a limitation value for nitrite concentration in coastal seawater. However, compared with ASEAN criteria (55  $\mu\text{g/l}$ ) for protection of aquatic life, Ninh Binh waters were not contaminated with nitrite [9]. The concentration of nitrite was high nearshore to the depth of 10 m, then gradually decreased

offshore. In the rainy season, nitrite concentration in seawater was higher than that in the dry season due to the influence of waste discharging from land through river mouths, even at a water depth of 15 m.

#### *Nitrate ( $N-NO_3^-$ )*

Nitrate concentration in the water in Ninh Binh coastal areas was in range of 40.8  $\mu\text{g/l}$  to 208.5  $\mu\text{g/l}$ , the average value was of 108.66  $\mu\text{g/l}$ . The increase of nitrate concentration in seawater in the rainy season was quite similar to that of nitrite parameter, related to the waste source from land. The concentration of nitrate was high in the water of tidal flat area, then gradually decreased from nearshore to offshore. This reduction was clearly observed during the dry season. Vietnam does not regulate limitation for nitrate concentration in coastal water while ASEAN criteria for nitrate concentration in protection of aquatic life is 60  $\mu\text{g/l}$ . Compared to ASEAN criteria for nitrate, most of the analysis samples of nitrate in coastal water of Ninh Binh were higher than limitation value.

#### *Ammonium ( $N-NH_4^+$ )*

The concentration of ammonium in seawater of Ninh Binh coastal area in the 2015 survey was in the range of 55.8–191.2  $\mu\text{g/l}$ , an average value of 86.10  $\mu\text{g/l}$  in dry season and 104.54  $\mu\text{g/l}$  in rainy season. Ammonium concentration in water of the tidal flat area was quite high, higher than limitation value regulated in QCVN 10-MT: 2015/BTNMT for coastal water (100  $\mu\text{g/l}$ ) from 1.4–1.9 times. Spatially, the concentration of ammonium in seawater tended to decrease from nearshore to offshore. At the water depth of 15 m, the concentration of ammonium was about 66.97  $\mu\text{g/l}$  in the dry season and 88.03  $\mu\text{g/l}$  in the rainy season, lower than limitation value (fig. 4). The water depth below 10 m was only contaminated with ammonium in rainy season. Over time, the ammonium concentration in seawater tended to increase in value during rainy season, in which the average concentration of ammonium in rainy season was 1.2 times higher than that in dry season. At the Cua Day fixed station, the highest difference in ammonium concentration between

samplings was about 13.5  $\mu\text{g/l}$  in dry season and 24.0  $\mu\text{g/l}$  in rainy season and the average concentration was below limitation value.

#### *Total nitrogen (T-N)*

In Ninh Binh coastal area, the total nitrogen concentration in water ranged from 0.75–5.35 mg/l, the average value was 1.62 mg/l. At the tidal flat area, the total nitrogen concentration in water was 2–3 times higher than that of the under-tide area. In the rainy season, the concentration of T-N in water was 1.2–1.7 higher than that in dry season. In a day, at the Cua Day fixed station, the daily average value of T-N in water was 0.82 mg/l in dry season and 1.58 mg/l in rainy season. In surface water layer, the value of T-N was 1.1 times higher than that in the bottom layer in dry season and 1.4 times in rainy season.

#### *Phosphate ( $P-PO_4^{3-}$ )*

In the waters of Ninh Binh area, the concentration of phosphate in water ranged from 17.87  $\mu\text{g/l}$  to 50.28  $\mu\text{g/l}$ , the average value was 26.69  $\mu\text{g/l}$ . Phosphate concentration was uniform in the under-tide area. In rainy season, the concentration of phosphate in seawater tended to increase higher than that in dry season, but the difference was low. At tidal flat area, the concentration of phosphate was about 1.4–2.7 times higher than that of the under-tide area. In a day, the phosphate concentration was not much different between the samplings, the average value was 24.93  $\mu\text{g/l}$  in dry season and 27.40  $\mu\text{g/l}$  in rainy season. Compared to the limitation value regulated in QCVN 10-MT: 2015/BTNMT (200  $\mu\text{g/l}$ ) for coastal water, seawater in Ninh Binh was not polluted by phosphate.

#### *Total phosphorous*

Total phosphorus concentration in Ninh Binh waters fluctuated in the small range from 0.06 mg/l to 0.24 mg/l, the average concentration was 0.11 mg/l. In the tidal flat area, total phosphorus concentration was 1.6 to 1.6 times higher than that of the under-tide area. In a day, the difference in phosphorous concentration between the samplings in dry season was small, the average value of T-P in water at the Cua Day fixed station was 0.08 mg/l in dry season and 0.12 mg/l in rainy

season. Vietnam does not regulate limitation value of T-P, but compared with Australia Guideline for Fresh and Marine Water (T-P < 0.05 mg/l) [6], the T-P concentration in most of the analyzed samples exceeds this limitation from 1.2 to 5.0 times.

**Chlorophyll a**

According to Bricker et al., (1999, 2003), the eutrophication of water can be classified as follows by chlorophyll a concentration: Concentration of chlorophyll a is higher than 60 µg/l - the water is hyper eutrophication; from 20–60 µg/l - the water is high eutrophication; from 5–20 µg/l - the water is

medium eutrophication; less than 5 µg/l - the water is low eutrophication [10, 11].

In the Ninh Binh coastal area, concentration of chlorophyll a in water ranged from 5.18 µg/l to 15.02 µg/l, the average value was 8.57 µg/l. Thus, the seawater of Ninh Binh area had the eutrophication from medium to high (fig. 4). At the Cua Day fixed station, the concentration of chlorophyll a in water ranged from 5.37–8.86 µg/l, the average value was 7.08 µg/l in the dry season; and that ranged from 7.52 µg/l to 12.3 µg/l, the average value was 9.50 µg/l in the rainy season. It indicated that in rainy season, there was the increase of chlorophyll a content in the water sometimes.

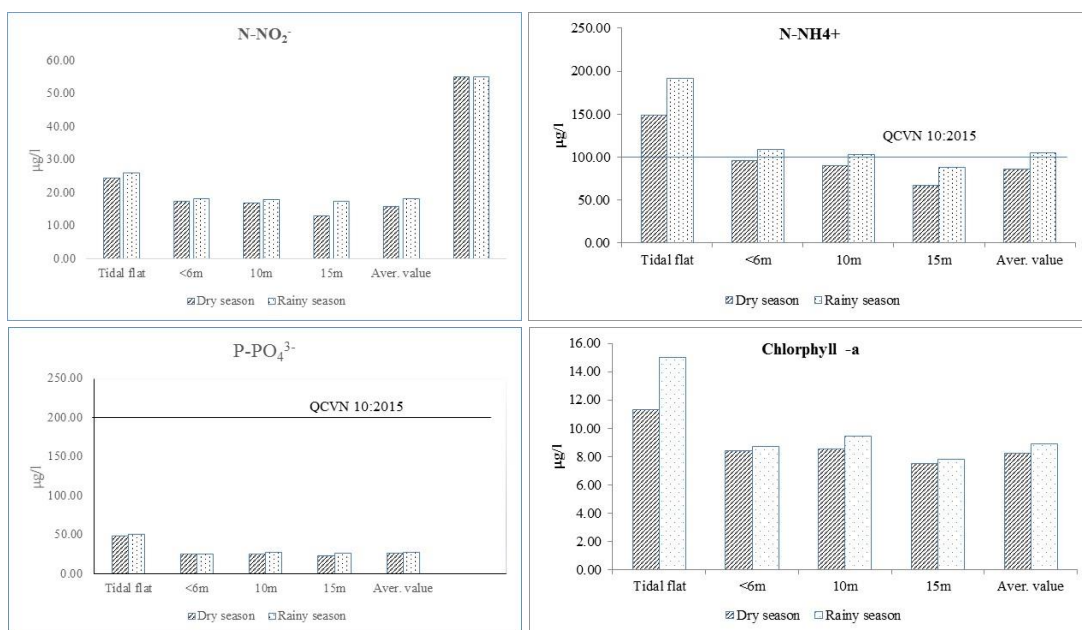


Fig. 4. Distribution of some nutrient factors in seawater of Ninh Binh in 2015

**Contaminant factors in seawater of Ninh Binh**

Contaminant factors in seawater were monitored including oil and grease, cyanide, heavy metals (Cu, Pb, Zn, Cd, Hg and As), organochlorinated pesticides and coliform density. Table 3 presents the content of these contaminants and coliform density in water in the study area.

**Oil and grease**

Oil and grease content in seawater of Ninh Binh area was quite low, ranging from trace

amounts to 0.21 mg/l, the average value was 0.04 mg/l. In general, Ninh Binh seawater was not polluted by oil and grease compared to Regulation of Vietnam in QCVN 10-MT: 2015/BTNMT, except for the tidal flat area in rainy season (fig. 5). In a day, the oil and grease content at the fixed station was also low, the highest was 0.11 mg/l in dry season and 0.13 mg/l in rainy season. The oil and grease content in water in transect III - the southern part of Ninh Binh coast was lowest. Compared to other sea areas of Vietnam (with values



ranging from undetectable to nearly 1 mg/l seawater was lower. [12]), the oil and grease content in Ninh Binh

Table 3. Concentration of some contaminant factors in seawater of Ninh Binh in 2015

Parameters	Dry season		Rainy season		Yearly aver value	Limitation value QCVN: 10/2015
	Range	Average value	Range	Average value		
Oil and grease (mg/l)	ND-0.13	0.03	ND-0.21	0.05	0.04	0.5
Cyanide (µg/l)	ND-1.96	0.76	ND-2.0	0.66	0.71	10
Coliform (MPN/100 ml)	0-420	126	0-520	90	108	1,000
Cu (µg/l)	21.1-31.4	27.41	23.7-35.3	31.19	29.3	200
Pb (µg/l)	0.8-7.0	3.18	0.2-4.9	2.66	2.92	50
Zn (µg/l)	13.8-25.9	17.96	14.3-37.0	24.31	21.14	500
Cd (µg/l)	0.1-0.25	0.19	0.12-0.55	0.26	0.22	5
Hg (µg/l)	0.02-0.2	0.13	0.13-0.22	0.17	0.15	1
As (µg/l)	16.7-29.1	22.89	11.56-31.34	21.74	22.3	20
Lindane (ng/l)	ND-2.69	0.98	ND-2.62	0.19	0.58	20
Aldrin (ng/l)	ND	ND	ND	ND	ND	100
Endrin (ng/l)	ND-2.17	0.98	ND-3.77	1.12	1.05	NR
Dieldrin (ng/l)	ND	ND	ND	ND	ND	100
4,4'-DDE (ng/l)	ND-2.72	0.34	ND-14.06	3.71	2.02	1000
4,4'-DDD (ng/l)	4.26-9.58	7.10	4.43-15.63	10.24	8.67	1000
4,4'-DDT (ng/l)	ND	ND	ND	ND	ND	1000
Total organochlorinated pesticides	7.85-11.33	9.40	ND-25.95	13.76	11.58	

Note: ND: Not detected; NR: Not regulated.

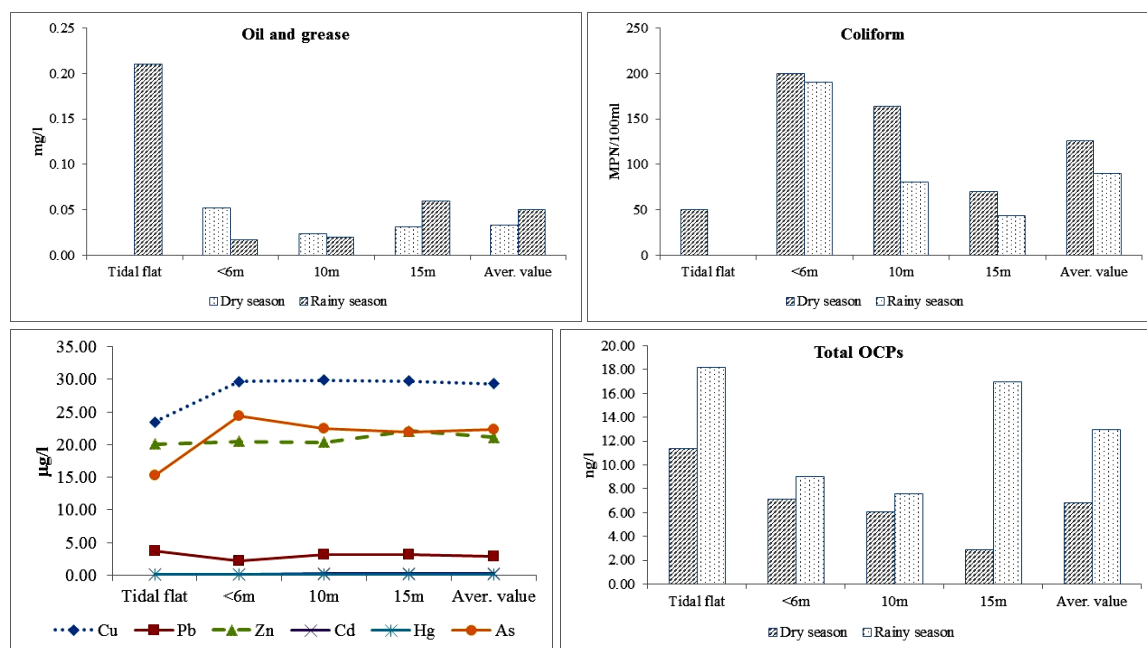


Fig. 5. Concentration of some pollutants in Ninh Binh coastal water in 2015

**Coliform density**

Coliform density in seawater of Ninh Binh ranged from 0-520 MPN/100 ml, the average

density was 108 MPN/100 ml. The highest density of coliform was distributed in the water area less than 6 m deep, then gradually

decreased offshore. Coliform density tended to be high in dry season, this was clearly shown by the results of Cua Day fixed station with the average value of 106 MPN/100 ml in dry season and 29 MPN/100 ml in rainy season. Compared with limitation value regulated in QCVN 10-MT: 2015/BTNMT for coastal water (1,000 MPN/100 ml), Ninh Binh seawater was not polluted by pathogenic bacteria.

### Cyanide

The concentration of cyanide in seawater of Ninh Binh was low, the value ranged from undetectable to 2 µg/l, the average concentration was 0.71 µg/l, lower than limitation value regulated in QCVN 10-MT: 2015/BTNMT for coastal water (10 µg/l). The fixed station results in 2015 also showed that seawater of Ninh Binh was not polluted by cyanide.

### Heavy metals

In the 2015 survey, some heavy metals tended to be distributed seasonally clearly such as Cu, Zn, showing the increasing trend in value during the rainy season; the remaining metals did not show clearly seasonal trends. In addition, the reducing trend of the concentration of heavy metals from nearshore to offshore was not found like other parameters, for example organic substances and nutrients (fig. 5). Compared with limitation value regulated in QCVN 10-MT: 2015/BTNMT for coastal water, seawater of Ninh Binh showed pollution of As in both rainy and dry seasons, except for tidal flat area. Compared to the nearby sea area of Thanh Hoa province (according to Tran Dinh Lan and colleagues), concentrations of heavy metals in

seawater of Ninh Binh were higher, especially Cu and As.

### Organochlorinated pesticides (OCPs)

In general, the organochlorinated pesticide compounds in Ninh Binh seawater were found at relatively low levels. There were 3/7 compounds not found in seawater, including: Aldrin, Dieldrin and 4,4'-DDT, other compounds were found with concentration ranging from trace amounts to several ng/l. Only 4,4'-DDD was found regularly in all samples with an average concentration of 7.10 ng/l in dry season and 10.24 ng/l in rainy season. If compared with limitation value regulated in QCVN 10-MT: 2015/BTNMT, seawater of Ninh Binh was not contaminated with these compounds. The distribution of the total organochlorinated pesticides during dry season clearly showed the decrease in the concentration from nearshore to offshore. But in rainy season, there was a high concentration of OCPs in the water depth of 15 m. This needs to be further studied in the future.

### General assessment of quality of coastal water in Ninh Binh

The calculated results of RQ in the water areas are shown in fig. 6–7. Fig. 6 shows that the seasonal average RQ of seawater for all parameters in Ninh Binh was within 0.24–0.50, the average value was of 0.34; so the water was safe for aquatic organisms. However, for individual element, water was polluted by three parameters: TSS, ammonium and As; water was at risk of dissolved oxygen deficiency. The remaining parameters were safe for aquatic organisms (fig. 7).

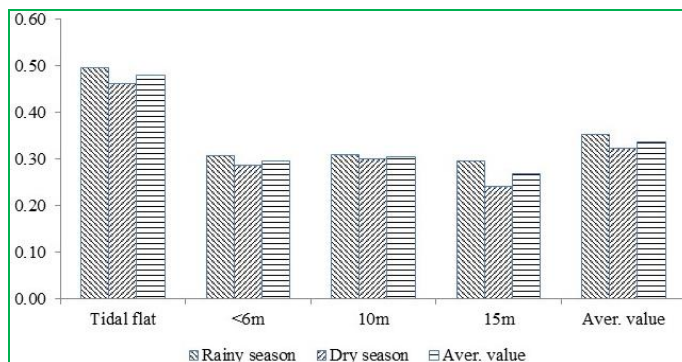


Fig. 6. Risk quotient for seawater quality Ninh Binh by depths

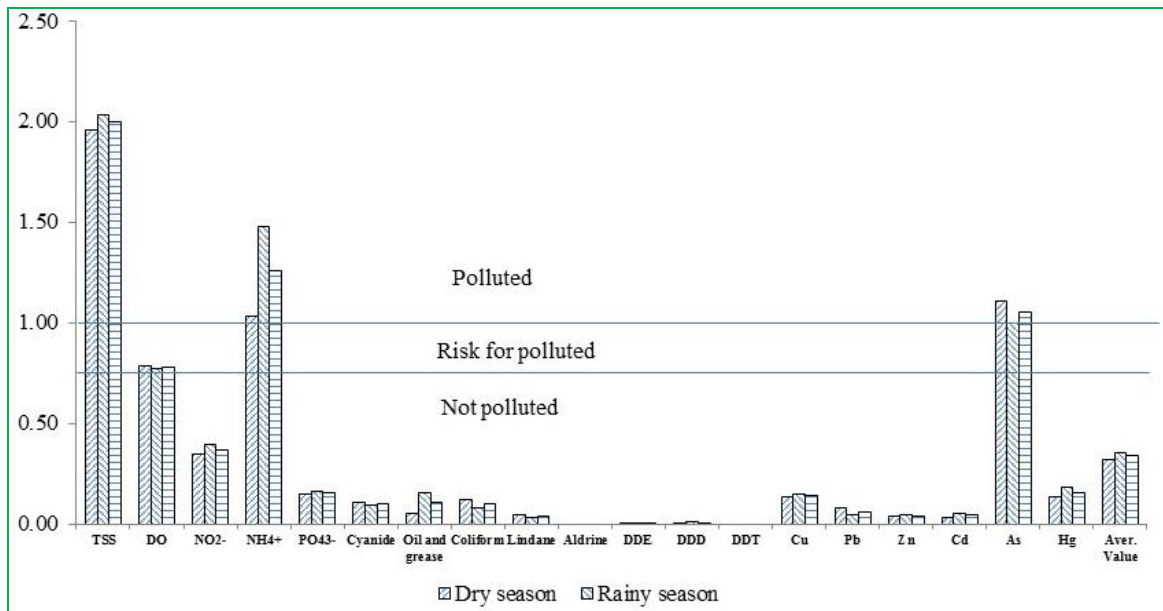


Fig. 7. Risk quotient for seawater quality in Ninh Binh by parameters

## CONCLUSION

The results of survey and analysis of physical and chemical parameters in Ninh Binh coastal water in 2015 showed that seawater had high turbidity, pH values ranged from neutral to weak alkaline. Salinity of water strongly fluctuated due to many river mouths flowing out, the water was brackish to saline. Ninh Binh seawater had a high demand for chemical oxygen consumption; although water did not show dissolved oxygen deficiency (the measured values > 5 mg/l), the risk quotient for DO was higher than 0.75; so the water was at risk of dissolved oxygen deficiency. In comparison with limitation values of Vietnam and ASEAN countries for coastal water used for protection of aquatic life, seawater of Ninh Binh was polluted by 3/21 parameters, including TSS, ammonium, and As. The RQ of water quality at different depths was from 0.24 to 0.50, so the water was still safe for aquatic organisms.

The concentration of pollutants in seawater of the study area tended to decrease from nearshore to offshore, and higher concentration occurred in the rainy season. In order to improve the quality of coastal water, Ninh Binh province needs to make big efforts to control waste sources from land, focusing on

wastewater treatment and waste source inventory.

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