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Environmental quality assessment of sandy beaches in Ha Long - Cat Ba area (Vietnam)

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ABSTRACT

The environmental quality of 6 famous sand beaches of the Ha Long - Cat Ba area was surveyed in July 2018 (the rainy season) and March 2019 (the dry season). The results showed that the pore water layer below the sand surface contained some pollutants exceeding the critical value of QCVN 10:2015/BTNMT for coastal water and ASEAN-criteria, including TSS, ammonium and nitrate. In the rainy season, the pore water quality was lower than that in the dry season, indicating that the tourism influenced the sandy beach water quality. Among the studied beaches, Ha Long and Bai Dai (Van Don) showed pore water pollution; the rest beaches were low to moderate pollution. Pore water in sandy beaches was charecterized by low dissolved oxygen saturation and high mineralization compared to sea water, thus confirming the role of sandy beaches in providing mineral nutrients to the sea. Analysis of the sediment grain size at the sandy beaches showed that the beach quality was medium to good. Forty-seven benthic fauna species were found on sandy beaches of the Ha Long - Cat Ba area, of which the dominant species were mollusks, followed by crustaceans, polychaetes, and echinoderms. The biodiversity of sandy beaches in study area was at an average level.

Keywords: Sandy beaches, pore water quality, sediment, benthic fauna.

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INTRODUCTION

Sandy beach is one of the critical marine resources types due to its benefits to human life: it is home to many species of economic value, serving the development of tourism for swimming and resorts. Sandy beach is also a soft belt to protect the coast from the impact of waves and sea processes [1–3]. Beach ecosystems provide numerous other goods and services [4]. Many beaches are berths for anchoring fishing boats to avoid storms for fishers. This type of resource is also sensitive and vulnerable to natural and human activities, especially the impacts of climate change and sea-level rise. The value of sandy beaches has not been paid much attention to by the human being and the scientific community. Sand beach is a reasonably popular resource all over Vietnam, but, research on this resource is still limited; many beaches are not managed and are used arbitrarily, thus leading to the risk of landscape deformation and degradation of the beach [5].

Pore water in sandy beaches is the osmotic water in the sediment of sea sand. The sediment-sand area of beaches is considered a filter containing or concentrating organic particles [6]. Ehrenhauss and Huettel (2004) [7] had shown that organic matter was degraded rapidly in sub-tidal permeable coastal sands, indicating that these sediments were very active sites of nutrient recycling. Pore water in sandy beaches is the osmotic water in sediment of sea sand. Pore water was released to the sea during ebb tide with mineralized organic matter [8]. Gibbes et al., (2008) [9] demonstrated that tidally driven pore water exchange within an offshore sandbank might be capable of delivering bio-available iron across the sediment-water interface. Sandy beaches also act as biogeochemical reactors, in which organic matter supplied by seawater that enters the pore space during a flood is trapped long enough to be mineralized. Recycled nutrients are efficiently brought back to seawater during ebb through tidally driven flow; the role of sandy beaches in nutrient biogeochemistry should not be overlooked in sandy tidal coasts [8].

Sandy beaches are vulnerable to erosion and sea-level rise or inland influences. A study on biogeochemical processes and dynamics in the sandy beaches can help preserve ecosystem services and assess beach ecosystems' vulnerablity [10]. Studying the characteristics of environment quality at beaches can evaluate the impact of inland sources on beaches.

The Ha Long - Cat Ba coastal area is located in the northeast of Vietnam, under the administrative management of Quang Ninh province and Hai Phong city. The coastline of the Hai Phong city - Quang Ninh province is about 375 km, with lots of beautiful beaches. Along with tourism - services, infrastructure, sand beaches have attracted many tourists to visit, swim and entertain. The number of tourists coming to Quang Ninh and Hai Phong city constantly increases over time, from nearly 3 million visitors in 2001 to 20 million visitors in 2018. For this reason, we selected several famous sand beaches in the Ha Long - Cat Ba area to be the study object and initial assessment of the environment quality and ecosystem of some sandy beaches in the area.

The study area in the region that affected by the tropical monsoon climate with two main seasons: the winter lasts from November to the following March, characterized by cold and dry weather; the summer lasts from April to October with hot and humid weather [11]. The average annual rainfall in Ha Long - Cat Ba coastal areas is very high, reaching more than 2,000 mm [12]. The tide of the study area is a typical diurnal tide [13] with the highest amplitude range up to 4.6 m. There are two spring tide cycles in a month with an average water level of 3.9 m and two neap tide cycles with an intermediate water level of 1.9 m.

The sandy beaches are distributed around small islands and coral reefs in the Ha Long - Cat Ba area. The beach is often exposed to the air at low tide. The components of beaches are sand, shells of bivalve (snails, oysters, clam), and dead coral. Although many sandy beaches are high, their area is small with quite a steep slope. According to Huong and Ve (2013) [5], there are 53 sandy beaches around Cat Ba Island, most of which are minor. There are 104 sandy beaches with very small area in Ha Long bay area, mainly distributed around small islands in the bay. This ecosystem is poor in

biological composition, but it has the most critical tourism value thanks to its sandy beach structure and materials.

In the context of this paper, some initial research results on the environment in sandy beaches in Ha Long - Cat Ba area (Viet Nam) have been assessed, serving as a basis for further studies on environment and dynamics of sand beaches.

METHODS

Studied area

Some sandy beaches in Ha Long - Cat Ba coastal area had been surveyed include Ha Long, Hong Van, Bai Dai, Quan Lan, Cat Co and Monkey islands (Figure 1). These sandy beaches are very famous and attract a high number of tourists every year.

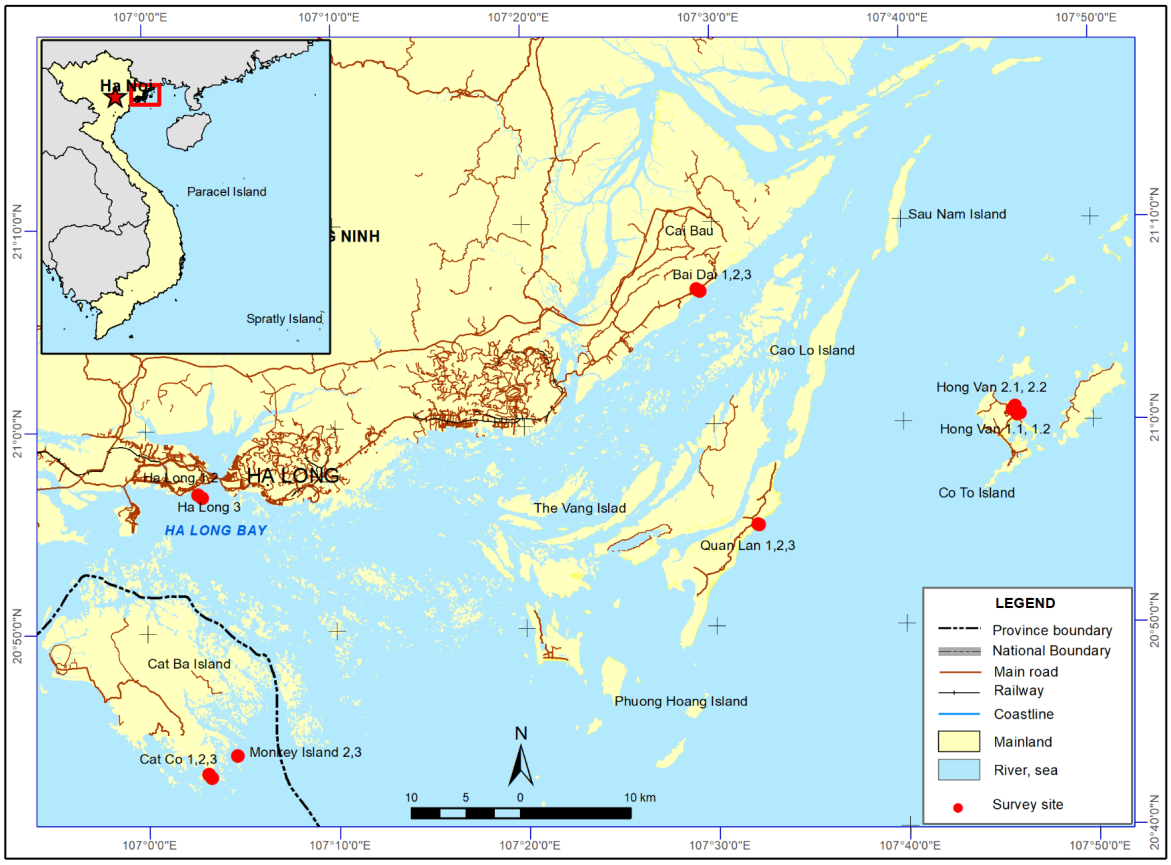

Figure 1. Sampling location for environment quality and biodiversity at the sandy beaches of Ha Long - Cat Ba area

Sampling of pore water samples and sediment samples

Pore water samples on the sand beaches were collected, following Jenifer E. D et al. (2011) [14]. Three sites were chosen for sampling at each sand beach, including a low tidal area (near the water edge), a mid-tidal area (in the middle of the sand beach), and a high tidal area (top upper of the sand beach). Besides, two water samples were taken in the sub-tidal zone at Ha Long and Cat Co beaches in July 2018, named Ha Long 3 and Cat Co 4 (see Table 1 for coordinate of sampling points).

Measurement of water quality parameters such as pH, temperature, dissolved oxygen (DO), turbidity, and salinity was done in situ using portable meters. The sampling point is a quantitative square size of 25 cm by 25 cm with a depth of up to 60 cm to form holes dug by a stainless-steel shovel. Water from the sediment

pores slowly filling the holes was collected in plastic bottles to analyze for COD, TSS, N-NO_2, N-NO_3^-, N-NH_4^+, P-PO_4^{3-}, N-T, P-T, chlorophyll a, oil and grease, and coliform. Pore water samples were fixed with reagents according to TCVN 5993:1995 (ISO 5667-3:1985) - Water quality - Sampling - Instructions for preservation and handling of samples [15], then put in cold boxes at a temperature of 4°C until analysis. The value of oxygen saturation (OS) was calculated from salinity, temperature and DO, using an on-line program of USGS namely DOTABLES (https://water.usgs.gov/water-resources/software/DOTABLES).

Table 1. Coordinates of sampling points at sandy beaches

No.	Sampling points	Coordinates	No.	Sampling points	Coordinates
1	Ha Long 1	20°56'48.7"N-107°02'52"E	11	Bai Dai 3	21°6'31''N-107°29'24''E
2	Ha Long 2	20°56'48.7"N-107°02'51.8"E	12	Quan Lan 1	20°54'25''N-107°31'36''E
3	Ha Long 1-2	20°56'51.7"N-107°03'02.3"E	13	Quan Lan 2	20°54'24''N-107°31'37''E
4	Ha Long 3	20°56'39"N-107°03'80"E	14	Quan Lan 3	20°54'23''N-107°31'38''E
5	Hong Van 1.1	21°0'23.56"N-107°45'54.32"E	15	Cat Co - 1	20°43'04.8"-107°03'10.4"E
6	Hong Van 1.2	21°0'23.84"N-107°45'54.76"E	16	Cat Co - 2	20°43'03"N-107°03'11.3"E
7	Hong Van 2.1	20°59'57.31''N-107°46'17.36''E	17	Cat Co - 2	20°43'3''N-107°3'12''E
8	Hong Van 2.2	20°59'57.50''N-107°46'18.06''E	18	Cat Co - 4	20°43'00.4"N-107°03'13.4"E
9	Bai Dai 1	21°6'36''N-107°29'21''E	19	Monkey island 2	20°43'55''N-107°4'47''E
10	Bai Dai 2	21°6'34''N-107°29'22''E	20	Monkey island 3	20°43'55''N-107°4'46''E

Besides, sediment sample were collected and put into plastic bags and kept in cold boxes for analysis of grain size and oil and grease content.

Pore water samples and sediment samples were collected in July 2018 (representing for rainy season) and March 2019 (representing for dry season). Samples were taken at the ebb tide of the spring tide period. There were 2–4 pore water samples and sediment samples collected at each sand beach.

Sampling of benthic fauna

Benthic fauna samples were collected following the methods of Eleftheriou and McIntyre, 2005 [16] and "Procedures for investigation, a survey of marine resources and environment" of Institute of Marine Environment and Resources (IMER), 2014 [17]. The benthic fauna was sampled by transects and quantitative squares, whose sampling site was similar to pore water and sediment samples, as shown in Figure 1. Each transect is divided into three zones, high-, mid-, and low-tide and samples were collected in the zones by surface space, using a square of 0.5 × 0.5 m. Samples were kept in plastic boxes in ethanol 70% until analysis in the laboratory [17].

Analysis in the laboratory

Analysis of pore water quality parameters complies with standard analysis documents of Viet Nam and the United States [18]. Methods were used as follow: Chemical oxygen demand (COD) - TCVN 6186:1996; Total suspended solids (TSS) - TCVN 6625:2000; Oil and grease in water - TCVN 5070:1995; Phosphate (P-PO_4^{3-}) and total Phosphorus - TCVN 6201:2008; nitrite (N-NO_2^-) - TCVN 6187:1996, ammonium (N-NH_3 + NH_4^+) and total Nitrogen - SMEWW4500-NH_3 F; Chlorophyll a - TCVN 6662:2000 (ISO 10260:1992).

The grain size of sediment was determined by pipetting method [19]. Oil and grease in sediment are determined following TCVN 5070:1995 after extraction with n-hexane.

The zoobenthos samples in the laboratory were analyzed using a stereomicroscope according to the authors Abbott R. T. (1967) [20]; Springsteen F. J and Leobreca C. B. (1986) [21]; Jorgen and Richard (2003) [22].

Data Processing

Up to now, no criteria have been given to assess the pore water quality. For beaches in the Ha Long - Cat Ba area, the National

Technical Regulation on Marine water quality QCVN 10-MT:2015/BTNMT to protect aquaculture and aquatic life and for entertainment was used to assess the quality of pore water [23]. In addition, use criteria of ASEAN for nitrite, nitrate [24], and Hong Kong [25] for chlorophyll a that are not specified in the National Technical Regulation. Besides, using the risk quotient RQ - the ratio of the number of pollutants in water divided by regulated critical value - for assessing water quality. When RQ < 0.1: The water is minimal risk, 0.1≤ RQ < 1: The water is a medium risk and RQ ≥ 1: The water is a high risk [26, 27]. As for DO, the RQ value of DO was calculated by dividing the regulated limitation value by the measured value.

For sediment grain size, we used the classification of Lisitizin (1986) [28] to classify sediments. The good quality beaches are those with medium sand structure (the mean particle diameter (Md) is in the range of 0.25–0.5 mm), fine sand (Md from 0.1–0.25 mm), and coarse sand (Md from 0.5–1 mm). The low-quality beach is the one structured from very fine sand (Md from 0.05–0.1 mmm) and gravel sand (Md > 1 mm).

The Shannon-Weiner (*H′*) diversity index was used to assess the biodiversity of benthic fauna on beaches. The Shannon-Weiner (*H′*) diversity index was calculated as follows [29]:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

in which: *S*: total number of species in the community (richness); p_i: proportion of *S* made up of the i^{th} species.

RESULTS AND DISCUSSION

Pore water quality in the Ha Long - Cat Ba area

The analytical results on pore water quality through two surveys in July 2018 and March 2019 were summarized and presented in Table 2.

July 2018 (the rainy season)

In July 2018, the water quality parameters measured in the field changed sharply between beaches in which the pore water temperature was in the range of 21.3–30.1^{o}C, the pH value was from 7.38–8.39, the salinity ranged wildly from 12–31‰, and the turbidity was in the range of 1.3 to 117.7 NTU. TSS concentration in pore water was from 25.6–448.4 mgL^{-1}, the TTS concentration was over the critical value regulated in QCVN 10:2015/BTNM (50 mgL^{-1}) for coastal water from 3.8–8.9 times at Ha Long beach and 2.8 times at Hong Van beach (high-tide area).

The dissolved oxygen concentrations in pore water at beaches was quite low, ranging from 1.77 mgL^{-1} (Ha Long, high-tide area) to 6.82 mgL^{-1} (Hong Van 2, low-tide area), corresponding to saturation from 24.1–100%. It is noted that the dissolved oxygen concentration in pore water at Ha Long beach was very low; the average value was 3.19 mgL^{-1}, indicating that organic waste from inland sources has a significant influence on the quality of pore water at this beach. Chemical oxygen demand ranged from 2.42–7.26 mgL^{-1}, the higher value recorded in Ha Long beach, reconfirming the pollution of organic matter at this beach.

The nitrite and nitrate concentrationin pore water ranged from 2.80–56.33 μgL^{-1} and 28.18–204.26 μgL^{-1}, respectively. Compared to ASEAN criteria for coastal water, the pore water in most beaches was polluted by nitrate from 1.1–3.4 times. Ammonium concentration was quite high, ranging from 30.34–617.78 μgL^{-1}, compared to the critical value in QCVN 10:2015/BTNMT for entertainment purposes (500 μgL^{-1}), only one pore water sample in Ha Long beach in July 2018 exceeded the limitation about 1.2 times. However, if compared to the critical value of aquatic life protection (100 μgL^{-1}), 54.5% of the pore water samples was over the critical value.

The N-T and P-T concentrations ranged from 1.14–2.25 mgL^{-1} and 0.06–0.21 mgL^{-1}, respectively. Chlorophyll a concentration was low, ranging from 1.14–3.34 μgL^{-1}, lower than the critical value of Hong Kong. Oil and grease content ranged from 0.23–0.55 mgL^{-1} of which there was 1 sample at Ha Long beach - a high-tide area over critical value.

The coliform density ranged from less than 10–150 CFU/100 mL, lower than the critical value in QCVN 10:2015/BTNMT (1,000 CFU/100 mL).

Table 2. Surveyed results of pore water quality in studied beaches

Parameters	Unit	July 2018 (rainy season)					March 2019 (dry season)					Critical value
		Cat Co (*n* = 2)	Cat Co - sub-tidal (*n* = 1)	Ha Long (*n* = 3)	Ha Long - sub-tidal (*n* = 1)	Hong Van (*n* = 4)	Cat Co (*n* = 3)	Monkey island (*n* = 2)	Bai Dai (*n* = 3)	Quan Lan (*n* = 3)	Hong Van (*n* = 4)	
Temperature	^{o}C	28.15±1.48	29.2	28.23±0.59	30.1	23.78±2.69	21.10±0.10	21.40±0.10	19.97±0.21	21.20±0.44	18.78±0.05	NR
pH		7.68±0.42	8.32	8.04±0.18	8.39	8.21±0.12	7.72±0.06	7.79±0.07	7.90±0.25	7.95±0.20	8.09±0.07	6.5–8.5
Salinity	‰	27.2±3.1	30	18.0±7.2	25	27.5±4.1	31.0±0.6	31.5±0.7	27.3±1.5	29.3±2.52	30.3±1.5	NR
Turbidity	NTU	6.0±5.9	1.3	65.9±45.1	2.5	7.1±9.0	2.4±0.3	3.9±2.0	154.2±164.4	9.70±12.65	29.4±40.0	NR
TSS	mgL^{-1}	66.0±29.1	25.6	286.8±140.9	48.4	63.15±	32.6±2.7	19.20±1.41	496.33±479.4	46.20±46.46	145.8±161.3	50
DO	mgL^{-1}	5.74±0.37	5.74	3.19±2.25	6.54	5.82±0.88	5.10±0.96	5.61±1.00	4.48±0.66	5.33±1.33	4.84±0.91	≥ 5
COD	mgL^{-1}	3.13±0.22	3.9	6.95±0.27	4.45	2.67±0.24	2.86±0.10	2.05±0.08	4.14±0.10	2.12±0.73	2.23±0.12	NR
$N\text{-}NO_2^-$	μgL^{-1}	33.13±32.82	5.84	9.13±9.14	7.96	9.84±1.60	24.8±23.1	5.92±1.77	14.84±9.50	3.67±1.07	9.37±7.42	55*
$N\text{-}NO_3^-$	μgL^{-1}	128.8±51. 5	63.63	110.0±81.6	78.46	55.30±37.75	106.9±32.6	84.6±11.0	95.20±22.38	82.87±11.64	148.1±37.3	60*
$N\text{-}NH_4^+$ □	μgL^{-1}	42.23±9.71	50.18	365.8±227.7	52.78	171.2±94.97	80.1±28.4	48.6±11.4	127.4±106.3	54.73±3.18	41.93±17.30	100
$P\text{-}PO_4^{3-}$	μgL^{-1}	38.35±20.41	20.63	36.38±10.42	33.29	26.31±6.81	20.68±3.33	16.92±3.14	44.21±10.20	20.12±18.27	31.17±3.83	200
N-T	mgL^{-1}	1.30±0.23	1.34	2.02±0.15	1.35	1.85±0.29	1.13±0.11	0.99±0.07	1.34±0.37	1.25±0.07	1.13±0.10	NR
P-T	mgL^{-1}	0.08±0.02	0.07	0.18±0.02	0.10	0.15±0.05	0.06±0.01	0.06±0.01	0.10±0.02	0.09±0.04	0.09±0.03	NR
Chlorophyll a	μgL^{-1}	1.68±0.22	1.78	3.21±0.13	3.34	1.61±0.39	2.41±0.16	1.64±0.12	5.40±0.61	2.39±1.20	3.69±1.72	10**
Oil and grease	mgL^{-1}	0.32±0.0	0.27	0.40±0.13	0.36	0.30±0.08	0.21±0.03	0.21±0.04	0.33±0.02	0.20±0.03	0.27±0.04	0.5
Coliform	CFU/100 mL	120±42	90	60±17	40	25±17	20±35	85±64	273±412	483±144	170±112	1,000

Note: Critical value is regulated in QCVN 10:2015/BTNMT for coastal water in protection of aquatic life; (*) ASEAN criteria; (**) Hong Kong criteria; NR-not regulated; *n* - number of sample.

Assessing the quality of pore water at beaches shows that: in the rainy season, pore water was contaminated by TSS and ammonium; the water was deficient in dissolved oxygen and oil pollution risk at Ha Long beach. In general, an average RQ index of pore water in Hong Van beach was 0.78 - the water was a median risk; the RQ index of pore water in Ha Long beach was greater than 1 - the water was a high risk; RQ index of pore water in Cat Co beach was 0.57 - the water was safe.

March 2019 (the dry season)

In March 2019, the pore water temperature was in the range of 18.7–21.5^{o}C, the pH value was lower than that in the rainy season and narrow changed from 7.67–8.19, the salinity ranged from 26–32‰, and the turbidity changed sharply from 2.0–341.0 NTU in which, the high turbidity was recorded at Bai Dai and Hong Van beaches. TSS concentration in pore water was from 15.0–1,045.0 mgL^{-1}; the beaches that polluted by TSS were Bai Dai (overcritical value near 10 times) and Hong Van (overcritical value near 3 times).

The concentration of dissolved oxygen in pore water at beaches was low, ranging from 3.53 mgL^{-1} (Hong Van, high-tide area) to 6.78 mgL^{-1} (Quan Lan, low-tide area), corresponding to saturation from 44.8–91.2%. However, these values were within the critical limitation.

Chemical oxygen demand ranged from 1.52–4.21 mgL^{-1}, lower than in the rainy season.

The nitrite concentration in pore water ranged from 1.86–51.39 μgL^{-1}, lower than ASEAN criteria for coastal water. The nitrate concentration in pore water ranged from 72.19–187.86 μgL^{-1}, higher than ASEAN critical from 1.2–3.1 times. Ammonium concentration was different between beaches, ranging from 32.44–249.68 μgL^{-1}, lower than the critical value in QCVN 10:2015/BTNMT for entertainment purposes (500 μgL^{-1}). However, compared to critical value for protecting aquatic life (100 μgL^{-1}), two beaches (Cat Co and Quan Lan) were polluted by ammonium in pore water in the high-tide area.

The N-T and P-T concentrations ranged from 0.44–1.75 mgL^{-1} and from 0.05–0.14 mgL^{-1}. Chlorophyll a concentration ranged from 1.48–5.99 μgL^{-1}, lower than the critical value of Hong Kong. Oil and grease content ranged from 0.18–0.36 mgL^{-1}, lower than the necessary value. The coliform density ranged from 0–750 CFU/100 mL, lower than the critical value.

In the dry season, the level of pollution decreases. The pore water still showed TSS pollution and was at risk of dissolved oxygen deficiency at all beaches. Except for Bai Dai (Van Don) had an average RQ of 1.59 - the water was a high risk, the left beaches was a median risk.

Figure 2 illustrates the risk quotient for pore water quality in the beaches of the Ha Long - Cat Ba area in 2018–2019, showing that the pore water at Bai Dai (Van Don) and Ha Long were at high risk, other beaches were a median risk.

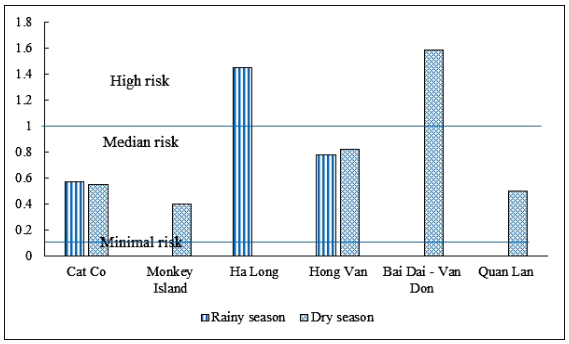

Figure 2. Risk quotient value of pore water quality in studied beaches in 2018–2019

Studies on other beaches worldwide show that the oxygen saturation (OS) in pore water is always lower than that in seawater [8, 30]. The survey results of the OS in pore water on beaches of Ha Long - Cat Ba area show an increase of OS in pore water from the high tide area to the low tide area (Figure 3). In the rainy season, the oxygen saturation in pore water at Cat Co and Hong Van beaches was quite high, from over 65–100%. But in Ha Long beach, the pore water of the beach was seriously lacking dissolved oxygen, with an oxygen saturation level of 24.1% in the high tide area to 28.5% in

the low tide area. However, it still demonstrated the increase of oxygen saturation from the intertidal area to under tidal area.

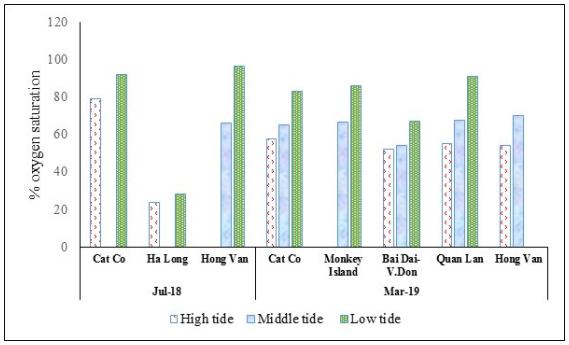

Figure 3. Oxygen saturation in pore water at the studied beaches in 2018–2019

The dissolved oxygen concentration in the seawater sample of Ha Long beach in July 2018 was 6.54 mgL^{-1} (corresponding to 99.39% saturation), so the difference in oxygen concentration compared to pore water was 3.35 mgL^{-1}, which means there were 104 μM of organic carbon mineralized.

Due to the organic mineralization, the concentration of mineral nutrients of nitrogen and phosphorus in water also increases in pore water samples compared to seawater samples. Pierre A. et al., (2008) [8] studied the concentrations of phosphorus and nitrate in pore water and seawater at Truc Vert Beach and found that the concentration of these substances in pore water exceeded their value in seawater in most cases. At the Ha Long beach area, in the sampling in July 2018, the total concentration of dissolved nitrogen in pore water ranged from 374.0–682.0 μgL^{-1}, which was much higher than seawater -139.2 μgL^{-1} (the Ha Long 3 sample). The phosphate concentration in the pore water in Ha Long beach ranged from 28.17–48.10 μgL^{-1}, an average of 36.38 μgL^{-1}, higher than the phosphate concentration in seawater -33,29 μgL^{-1} (the Ha Long 3 sample). Similar, at Cat Co beach in July 2018, the total dissolved nitrogen concentration in pore water was higher than that in seawater (257.84 μgL^{-1} compared to 119.65 μgL^{-1}); and concentration of phosphate in pore water was higher than that in seawater (52.78 μgL^{-1} compared to 20.63 μgL^{-1}). The difference between mineral nutrients in pore water and seawater indicates the sandy beaches' role in providing recycle nutrients to the sea [7]. This mechanism was confirmed by Gibbes et al., (2008) [9] in which sandy beaches act as biochemical reactors; organic matter provided by seawater enters pore space during the high tide period is trapped long enough to be mineralized.

Sedimentary quality of sandy beaches

Grain size

Sediment grain size is an essential parameter for assessing sediment quality and beach quality. The analytical results of grain size of sandy beaches in the area in 2018–2019 showed that sediments were structured mainly from medium and fine sands with Md in the range of 0.17–0.47 mm, which means that the quality of the beach was from medium to good. Most of the sandy beaches in the Ha Long - Cat Ba area are small (less than 1 ha) distributed along with the limestone islands.

Oil content

The analysis of oil content in sediments at the sandy beach shows that the value of oil was in the range of 5.00–68.69 mg/kg dry weight (Fig. 4), lower than the critical limit of Vietnam regulated in QCVN 43:2012/BTNMT - 100 mg/kg dry weight for total hydrocarbon [31]. In the dry season, the oil content in sediments at sandy beaches tended to increase compared to that in the rainy season.

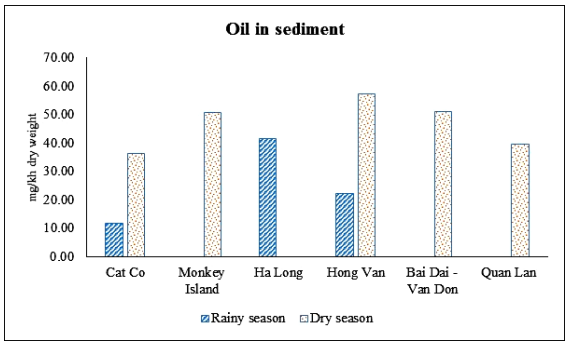

Figure 4. Oil content in sediment of sandy beach ecosystem of Ha Long - Cat Ba area

Benthic fauna

Through this study, 47 species of benthic fauna were investigated on the sandy beaches of the Ha Long - Cat Ba area, in which the dominant species were mollusks, followed by crustaceans, polychaetes, and echinoderms. The number of species of benthic fauna on the sand beaches was quite poor compared to the benthic fauna in Ha Long bay 571 species [32] and Cat Ba of 210 species [33].

The diversity of benthic groups at the studied sandy beaches varied slightly, the area with the most diverse number of species was Cat Co, and Quan Lan with 16–17 species, Bai Dai (Van Don) with 11 species, the remaining beaches had less than 10 species. The average density of benthic groups in the studied beaches reached 30 individuals/m^2. The dominant density was mollusks group with an average of 39 individuals/m^2, followed by the polychaetes group - 29 individuals/m^2, crustacean - 27 individuals/m^2. Typical species on sandy beaches are *Donax semigranosus*, *Tellina autralia* (mollusks group), *Mictyris longicarpus* (crustaceans group), *Laonice* sp. (polychaetes group) - Figure 5.

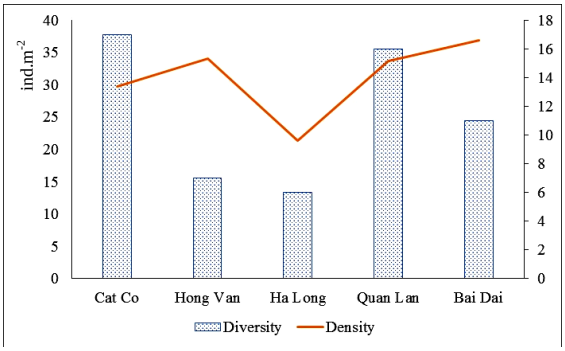

Figure 5. Diversity and density of benthic groups in studied sandy beaches

The research results show that the diversity of benthic species composition was significantly different according to the distribution of intertidal zones. The area with high variety was the low-tidal area with 33 species; the lowest diversity was a high-tidal area with 15 species. The dominant species in sub-tidal areas were of polychaetes group such as *Namalycastis indica*, *Nephtys dibranchis*, *Glycinde* sp., *Terebellides stroemi*, *Polyophthalmus pictus*. The dominant species in the mid-tidal area were crustacean group include *Scopimera longidactyla*, *Mictyris longicarpus* and *Hemigrapsus penicilatus*. Meanwhile, the mollusks species were more prevalent in the high-tidal area, including *Donax semigranosus*, *Meretrix meretrix*.

Assessment of the Shannon-Weiner (*H′*) diversity index in the study areas shows that the *H′* index in the sandy beaches in Bai Dai, Quan Lan, and Cat Co areas was higher than 2. In general, the biodiversity of sandy beaches in the study area was in average level (Figure 6).

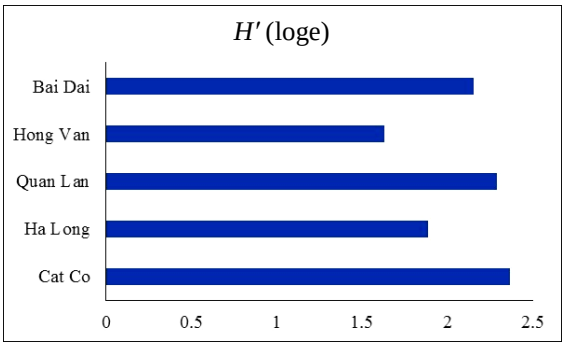

Figure 6. Biodiversity index of studied sandy beaches

CONCLUSION

Research results on zoo benthos' environmental quality and biodiversity at six sandy beaches in the Ha Long - Cat Ba area show dissolved oxygen deficiency in pore water, especially in the rainy season. Pore water in some beaches was turbidity, and high TSS concentrations, such as Ha Long, Bai Dai and Hong Van beaches, probably related to the beaches' reclamation. Pore water was high concentration of ammonium, affecting to sandy beach ecosystems. In the rainy season, the pore water quality was lower than that in the dry season, indicating that the source of tourism waste influenced the sandy beach water quality. Among the studied beaches, Ha Long and Bai Dai (Van Don) showed pore water pollution; the rest beaches were low to moderate pollution.

The grain size of sediment at the sandy beaches shows that the quality of beach was from medium to good. The survey results have

recorded 47 species of zoobenthos in the Ha Long - Cat Ba area, of which the dominant species are molluscs, followed by polychaetes and echinoderm.

Studies have shown that pore water on beaches was characterized by high mineral nutrient concentration and lower oxygen saturation than seawater. They act as a filter to provide minerals for the sea. They are distributed from high tide to low tide and the sea, mineralization level decreases, and oxygen saturation increases, indicating that sandy beaches are the environment for biogeochemical reactions of the sea. Therefore, the protection of sandy beaches from pollution and urbanization should be considered and paid more attention to in the coming time.

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