ASSESSMENT OF WATER QUALITY AT FISH CAGES IN THE NORTH OF VIETNAM

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ABSTRACT

Marine fish cages in the north of Vietnam contribute to the growth of the local economy. However, these areas are facing with the risk of environmental pollution and ecosystem degradation which can cause the outbreaks of fish disease. We investigated water quality at fish cages in Hai Phong city and Quang Ninh province, areas representative for the impacts of human activities and aquaculture in the north of Vietnam. The Risk Quotient (RQ) method was used as an indicator of pollution over a seven year period, from 2005 to 2012. DO concentration in Quang Ninh province and Hai Phong city decreased significantly from 2005 to 2012. Some areas with high density of fish cages, such as Ben Beo, Tung Gau (Hai Phong) and Kenh Ba Men, Cua Van (Quang Ninh), often had low levels of DO (<5.0 mg/l). From 2008 to 2012, the nutrient concentrations increased significantly, especially N-NH_4 and N-NO_3. Concentrations of heavy metals (Cu, Pb, Cd and Zn) increased significantly from 2005 to 2012. The RQtt value based on the Vietnamese environmental standards was found to be below the environmental safety (RQtt <0.75) in both regions, however, high levels of pollution were still found in areas of high density of fish cages, such as Cua Van-Quang Ninh. Based on the ASEAN standard, the RQtt values for both areas were above the environmental safety, highlighting the risk of disaster and environmental impacts on aquatic farming activities.

Keywords: Fish cages, Hai Phong, Quang Ninh, The Risk Quotient (RQ) method.

Đánh giá chất lượng nước khu nuôi cá biển bằng lồng bè ở miền Bắc Việt Nam

TÓM TẮT

Nuôi cá biển bằng lồng bè ở phía Bắc của Việt Nam đóng góp lớn vào sự tăng trưởng kinh tế địa phương. Tuy nhiên, các khu vực nuôi này đang phải đối mặt với nguy cơ ô nhiễm môi trường và suy thoái hệ sinh thái, được dự báo là một trong những nguyên nhân gây ra dịch bệnh đối với các đối tượng nuôi. Thành phố Hải Phòng và tỉnh Quảng Ninh là các khu vực đang phải chịu ảnh hưởng lớn từ hoạt động phát triển kinh tế xã hội và nuôi trồng thủy sản ở miền Bắc Việt Nam. Sử dụng chỉ số tai biến môi trường (RQ: Risk Quotient) để đánh giá chất lượng nước khu nuôi trong khoảng thời gian từ 2005 đến 2012. Nồng độ ôxy hoà tan trong nước (DO) khu vực nuôi ở Quảng Ninh và Hải Phòng có chiều hướng giảm rõ rệt từ 2005 đến 2012. Nồng độ DO thấp hơn giới hạn cho phép (<5,0 mg/l) xảy ra tại Bến Bèo, Tùng Gấu (Hải Phòng) và Kênh Bà Men, Cửa Vạn (Quảng Ninh). Trong thời gian từ 2008 đến 2012, nồng độ dinh dưỡng trong nước tăng đáng kể, đặc biệt với thông số N-NH_4^+ và N-NO_3^-. Nồng độ một số kim loại nặng (Cu, Pb, Cd và Zn) trong nước tăng trong thời gian từ 2005 đến 2012. Giá trị chỉ số tai biến môi trường tổng thể (RQtt) tính theo tiêu chuẩn môi trường Việt Nam nằm trong giới hạn an toàn (0,75) ở Quảng Ninh và Hải Phòng. Tuy nhiên, ô nhiễm cục bộ xảy ra ở khu vực nuôi với mật độ cao như Cửa Vạn (Quảng Ninh), Bến Bèo (Hải Phòng). Chỉ số tai biến môi trường tính theo tiêu chuẩn của ASEAN cho giá trị vượt giới hạn an toàn, điều này cho thấy sự ảnh hưởng của ô nhiễm môi trường và dịch bệnh đến hoạt động nuôi cá biển bằng lồng bè tại cả hai khu vực trên.

Từ khoá: Chỉ số tai biến môi trường, Hải Phòng, lồng bè, Quảng Ninh.

1. INTRODUCTION

Coastal areas in the north of Vietnam have many advantages for the development of fisheries economy. Marine fish cage farming here contributes to the growth of the local economy. However, these areas are facing with the risk of environmental pollution and ecosystem degradation, which can cause outbreaks of fish disease. For this reason it is important to encourage the management and protection of water resources, as these are essential requirements to stabilize economic development in the future.

Environmental risk assessment of pesticides, other chemicals and water parameters often uses the Risk Quotient (RQ) method to express risk quantitatively. RQ is calculated by dividing environmental exposure by toxicity (Robert, 2006). This study used the Risk Quotient (RQ) method as an indicator of pollution in fish cages in order to understand the status and trends of environmental water quality in Hai Phong city and Quang Ninh province, Vietnam over seven year period from 2005 to 2012. The study intends to contribute to scientific basis for decision makers and for public information.

2. MATERIALS AND METHODS

2.1. Documentation

Data used in the report were the results of research: "Monitoring, Warning Environmental quality at fishing ports, fish cages and marine protected areas in Vietnam" from 2005 to 2012 (Khanh, 2005 - 2012) and a number of reference documents related to locals.

2.2. Research Methodology

Samples were taken from high-density fish cages in the coastal areas of Quang Ninh province and Hai Phong city (Fig. 1). Samples were collected twice per year at low tides in May (the last dry season period) and October (the last rainy season period).

The parameters tested included concentrations of dissolved oxygen (DO), N-NO_2, N-NO_3, N-NH_4, P-PO_4, Cu, Pb, Cd, Hg, oil and cyanide (CN^-). Pollution levels were compared against the Vietnamese environmental standards (QCVN 10:2008/BTNMT and KT 03-07) and ASEAN standard (APHA, 1995; The ministry of Environment, 2008).

The Risk Quotient index RQtt (RQ overall) used to assess the quality of the environment in each region was determined using the formula:

$$RQ_{tt} = \frac{1}{n} x \sum_{i=1}^{n} (RQ)_i$$

RQ is calculated by dividing the estimated environmental concentration by the reference value for toxicity (reference values were taken from the Vietnamese environmental standards and ASEAN standard).

The environmental quality was assessed through the levels of RQtt as follows:

- If RQtt <0.25: very low risk of environmental harm
- If 0.25 <RQtt <0.75: low risk of environmental harm
- If 0.75 <RQtt <1.0: the risk of environmental harm
- If RQtt> 1.0: high risk of environmental harm

3. RESULTS AND DISCUSSION

3.1. Variations of environmental parameters

+ DO concentration

The results showed clear declines in DO levels in the marine fish cages sampled in Quang Ninh and Hai Phong in both dry and rainy seasons. The DO level dropped significantly over the course of the study, reaching its lowest value in 2012 (Fig. 2). Some areas with low DO concentrations (<5.0 mg/l - QCVN 10: 2008/BTNMT) were found where there was high density of fish cages, namely Kenh Ba Men and Cua Van in Quang Ninh province as well as Ben Beo in Hai Phong city. The low levels of DO could be demonstrated by using aerators to supply oxygen for fish at some fish cages at Ben Beo, Hai Phong in 2012.

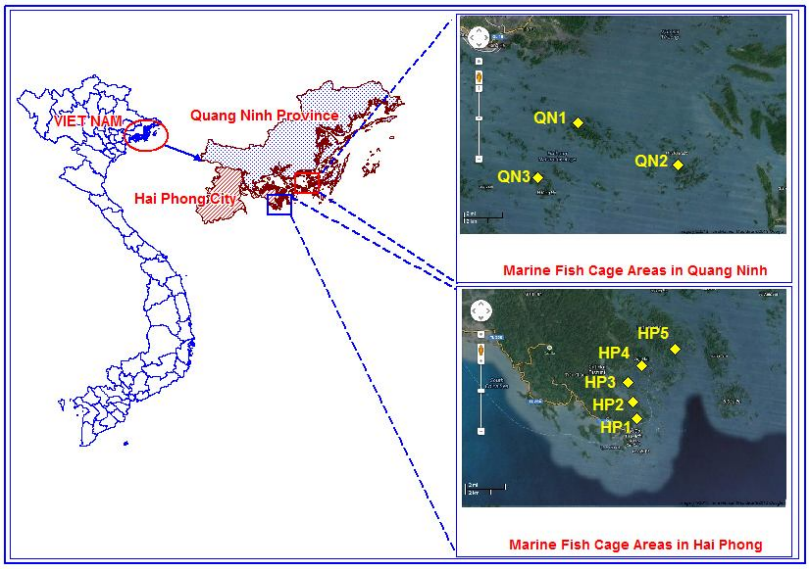
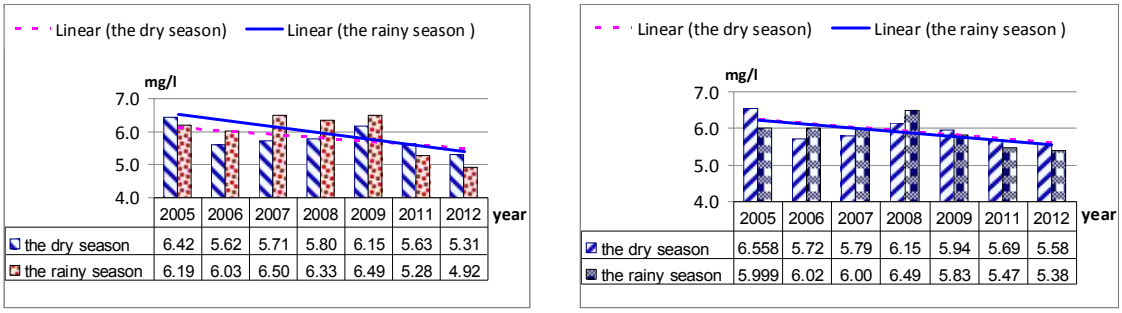


Fig. 1. Map of the location of sampling sites



a. Quang Ninh b. Hai Phong

Fig. 2. DO concentrations in marine fish cages in Quang Ninh and Hai Phong (2005 - 2012)

+ Dissolved inorganic nutrients

In Quang Ninh, the concentrations of nutrients in fish cages were found to increase gradually. Although changes in concentrations of N-NO_2, N-NO_3 were not significant between 2005 and 2007, the level of N-NH_4 reduced dramatically. From 2008 until the end of the survey, the nutrient concentrations increased significantly, especially N-NH_4, N-NO_3 (Fig. 3 and Table 1).

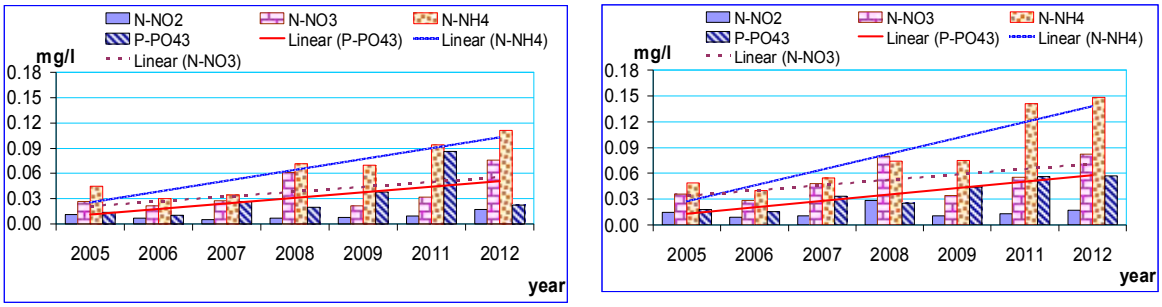
In Hai Phong, the concentrations of most parameters tested were found to increase over the study period. The concentrations of nutrients in 2012 were much higher than in 2005, P-PO_4 (more than 3.2 times), N-NO_3 (more than 2.2 times) and N-NH_4 (more than 3.0 times) (Fig. 3 and Table 1).

The concentration of N-NH_4 was highest among dissolved inorganic nutrients. N-NH_4 is not only toxic to fish, but is also an indicator of organic matter decomposition in the water and sediment. In 2012, the concentration of N-NH_4 exceeded the acceptable limit (0.1 mg/l) in Ben Beo and Tung Gau (the highest density of fish cages in Quang Ninh province). The N-NH_4 levels were found to be 1.3 to 1.9 times the permissible

limit specified in the Vietnamese environmental standard. The concentrations of N-NH_4 in Quang Ninh and Hai Phong were lower than those of fish cage areas in Nghi Son Bay (N-NH_4: 0.26 mg/l in 2012) (Thu, 2012). The recent studies, also conducted at the fish cages in Quang Ninh by Tai (2012), found similar high concentration of N-NH_4. It has been shown (Tho, 2004 and Tai, 2012) that high nutrient concentrations in the water are related to, and are one of the causes, of disease which occurs in fish.

+ Heavy metals

Although concentrations of the heavy metals were found to be within acceptable standards (QCVN 10: 2008/BTNMT), their levels were found to increase slightly over the study period. In Quang Ninh, Pb concentration in 2012 was 1.6 times as high as that recorded in 2005. From 2005 to 2012, Cd concentrations increased sharply, to more than doubled (Fig. 4). A similar pattern was found in Hai Phong, where the concentration of Cd increased to 2.3 times, Pb (1.9 times), Cu and Hg (1.3-1.4 times) between 2005 and 2012 (Fig. 5). Compared with the study of Thuoc (2010) in offshore of the Gulf of Tonkin, the concentrations of heavy metals in the water in Cat Ba (Hai Phong) were significantly higher due to the activities, such as mining, heavy industrial operation...) from the area of Quang Ninh and Hai Phong. The concentrations of heavy metals in Quang Ninh and Hai Phong were similar to those of fish cage farming areas in Nghi Son Bay (Cd: 0,201 µg/l, Hg: 0,211 µg/l in 2012) (Thu, 2012).

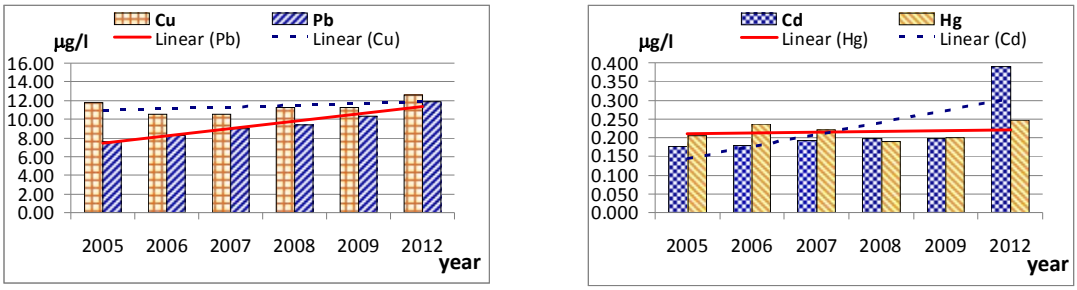


a. Quang Ninh b. Hai Phong

Fig.3. Concentrations of dissolved inorganic nutrients in marine fish cages in Quang Ninh and Hai Phong (2005 - 2012)

Table 1. Average concentrations of dissolved inorganic nutrients in marine fish cages in Quang Ninh and Hai Phong

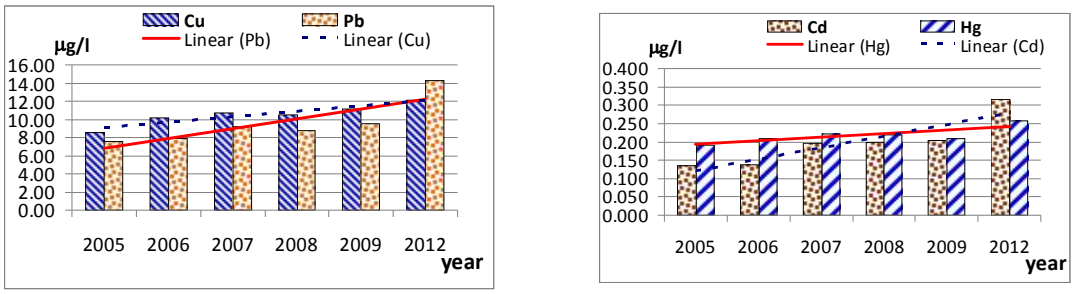
Areas / Years	Quang Ninh				Hai Phong			
	$N\text{-}NO_2$	$N\text{-}NO_3$	$N\text{-}NH_4$	$P\text{-}PO_4$	$N\text{-}NO_2$	$N\text{-}NO_3$	$N\text{-}NH_4$	$P\text{-}PO_4$
2005	0.011	0.027	0.045	0.014	0.015	0.036	0.049	0.018
2006	0.007	0.021	0.030	0.010	0.009	0.029	0.040	0.015
2007	0.005	0.028	0.035	0.026	0.011	0.048	0.055	0.033
2008	0.007	0.061	0.072	0.020	0.029	0.080	0.074	0.025
2009	0.008	0.022	0.069	0.038	0.011	0.034	0.075	0.044
2011	0.010	0.032	0.094	0.086	0.013	0.055	0.141	0.056
2012	0.017	0.075	0.111	0.022	0.017	0.082	0.148	0.057



a. Cu, Pb concentrations

b. Cd, Hg concentrations

Fig.4. Trend of concentrations of heavy metals at marine fish cages in Quang Ninh (2005 - 2012)



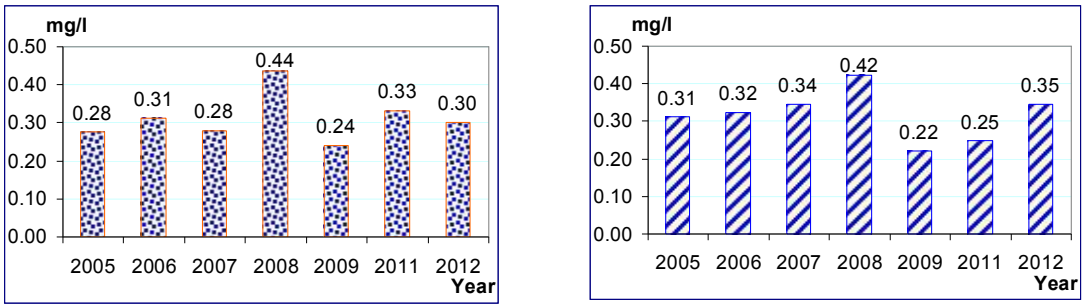
a. Cu, Pb concentrations

b. Cd, Hg concentrations

Fig.5. Trends of average concentrations of heavy metals in marine fish cages in Hai Phong (2005 - 2012)

+ Oil and cyanide

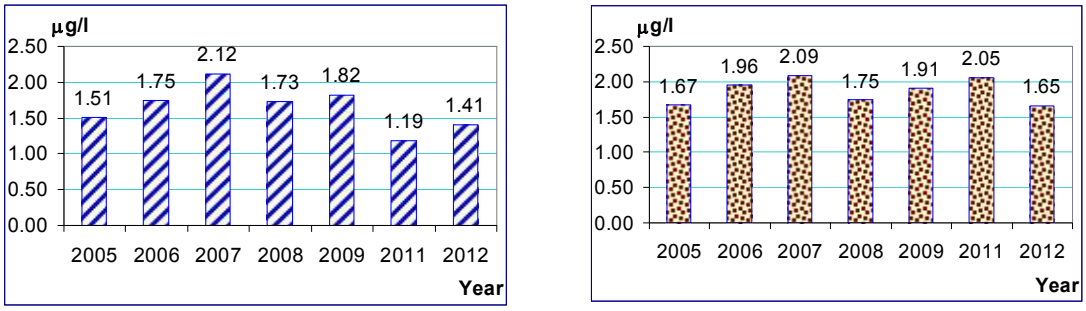
Average oil concentration ranged from 0.103 to 0.757 mg/l (Fig. 6). According to the Vietnamese environmental standard, there existed oil contamination in the water at Cat Ba. In 2012, oil concentration ranged from 0.113 to 0.574 mg/l; the highest oil concentration of 0.574 mg/l was found during low tides in the rainy season at Ben Beo, Hai Phong (Fig. 6). Research undertaken by Thu (2012) at Cat Ba also showed high oil concentrations.



a. Quang Ninh

b. Hai Phong

Fig.6. Average concentrations of oil in marine fish cages in Hai Phong (2005 - 2012)



a. Quang Ninh b. Hai Phong

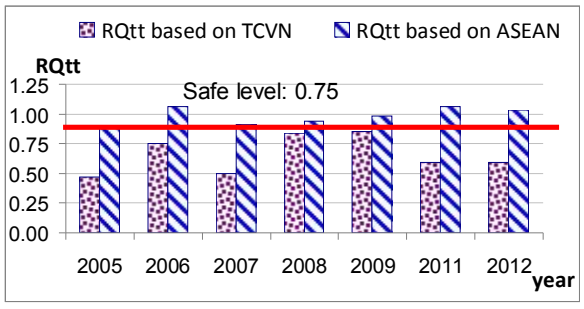
Fig.7. Average concentration of cyanide in marine fish cages in Quang Ninh and Hai Phong (2005 - 2012)

CN-concentrations in seawater ranged from 0.79 to 3.30 µg/l (Fig. 7). In 2012, during the low tides, CN- concentrations reached 2.19 µg/l and 2.09 µg/l in Ben Beo and Tung Gau, respectively. CN- concentrations during low tides were found to be higher than those during high tides at Cat Ba. This is likely to be related to waste from mining activities in the area of Quang Ninh and fish catching using anesthesia materials in Hai Phong and Quang Ninh.

3.2. The Risk Quotient

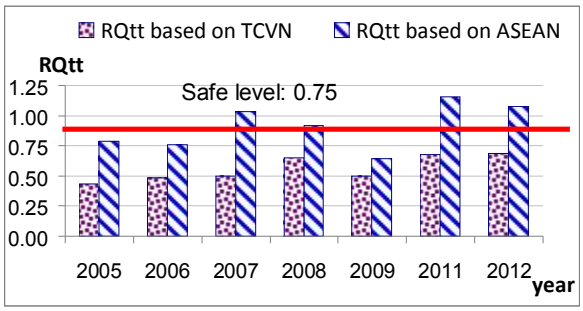
The Risk Quotient assessed the level of environmental quality in coastal areas where fish cage farming takes place, was based on the Vietnamese environmental standards and the ASEAN standard.

The RQtt based on the Vietnamese environmental standards was below the safe environmental level (RQtt <0.75) in both study areas. However pollution was found where there was a high density of fish cages in Cua Van, Quang Ninh. The RQtt based on ASEAN standard showed that both regions were at a level of disaster risk and environmental impact which can cause hazards to aquatic farming activities (Fig. 8).



Year	2005	2006	2007	2008	2009	2011	2012
RQtt (TCVN)	0.43	0.48	0.50	0.65	0.50	0.68	0.69
RQtt (ASEAN)	0.79	0.76	1.03	0.91	0.64	1.16	1.08

a. Quang Ninh



Year	2005	2006	2007	2008	2009	2011	2012
RQtt (TCVN)	0.47	0.75	0.50	0.84	0.85	0.60	0.59
RQtt (ASEAN)	0.88	1.06	0.91	0.94	0.98	1.07	1.04

b. Hai Phong

Fig. 8. Application of the risk quotient at fish cages in Hai Phong and Quang Ninh over a period of seven years from 2005 to 2012

3.3. The sources of environmental pollution

The decomposition of organic matter created dissolved nutrients in water, such as $N\text{-}NO_2$, $N\text{-}NO_3$, and $N\text{-}NH_4$. High concentrations of $N\text{-}NH_4$ in water are toxic to aquatic animals. In conditions of high temperature the metabolism of $N\text{-}NH_4$ to $N\text{-}NO_2$ and $N\text{-}NO_2$ to $N\text{-}NO_3$ occurs faster and consumes more dissolved oxygen. This leads to lack of oxygen in water. High nutrient concentrations in the water provide a favorable environment for microorganisms and viruses. This leads to disease in aquaculture and harms aquatic animals.

+ Pollution from land: According to Lan (2011), each year the coastal waters of Ha Long Bay and Lan Ha Bay (Cat Ba) received about 43 thousand tons of COD, 9 thousand tons of BOD_5, 6 thousand tons of total nitrogen, nearly 2 tons of total phosphate, and 135 tons of heavy metals. It is predicted that by 2020 the discharge of pollutants into the bay from the mainland will have increased sharply (Table 2).

+ Pollution from fishery and aquaculture activities: The use of marine fish cages has rapidly increased at Cat Ba and is one of the causes of water pollution**.** According to 2012 statistics, there were 8,897 fish cages, over 100 ships travel services, business petrol and 1,000 fishing boats (Thu, 2012). In Hai Phong, there are often hundreds of fishing boats and other seafood operations. Cat Ba Bay has about 300-400 ships. The municipal waste (estimated at 0.5 kg/person/day, about 4-5 people each ship), oil and grease from vehicles were not collected and pollutes of the coastal environment (Thu, 2012; Khanh, 2012).

+ Tourism activities: The number of tourists visiting Cat Ba is increased day by day and it also speeds up infrastructures serving for tourism. The statistic data showed that in 2003, the number of tourists visited Cat Ba was 250,000 people, doubled in 2006, 729,000 turns, in 2007 and more than 1.1 million people in 2010 (Hai Phong Security Newspaper, dated 30 March, 2011). A recent survey showed that the restaurants did not have waste treatment systems and discharged rubbish directly into the sea, polluting the aquatic environment (Tai, 2011). According to calculation, the amount of wastewater from tourists in Cat Ba Island increases 1.3 times in 2010 and 4 times by 2020 compared to that in 2007, respectively. Meanwhile, the capacity of domestic wastewater in the Island was 1400m^3/day, equivalent to 67% of wastewater amount treated (in 2007). Therefore, with the fast increase of tourists and tourism service, the possibility of water pollution is unavoidable, not including wastewater from ship and boat on bay (Lan et al, 2013).

Table 2. Total load of pollutants into the waters of Cat Ba, Ha Long, period 2008 - 2010 and 2020

Pollution	2008-2010 (ton/year)	Predicted by 2020 (ton/year)
COD	43,447.2	37,672.3
BOD_5	9,257.8	5,173.4
Total nitrogen	5,565.7	5,217.5
Total phosphate	1,977.7	2,671.3
As	0.117	0.059
Hg	0.022	0.011
Pb	19.343	15.210
Zn	77.248	60.832
Cu	38.708	30.483
TSS	77,745.5	73,648.6

Source: Lan et al. (2011).

According to Khanh et al (2006), 465 cages (34.6 m^3/cage) in Tung Gau-Cat Ba Island and 180 cages (60.3 m^3/cage) in Phat Co-Quang Ninh city were suitable for farming, based on calculation of environmental capacity in Hai Phong and Quang Ninh city. The present fish 572 farms with about 9,000 cages in Cat Hai district (as of 4 February, 2013), are encouraged to reduce by 40% of fish cages at the end of 2013 (compared to 2010). There are about 2,000 cages (compared with 1,440 cages as planned) in Lan Ha of Cat Ba Island and 454 farms with 1,500 cages in Ha Long bay (2013) (Hai Phong Newspaper). This means that the number of fish cages in some areas of Cat Ba Island is higher than that for sustainable aquatic culture.

Therefore, some measures need to be taken to have sustainable development in the areas:

- Continue to implement the Decision No. 1572 of the People's Committee of the detailed planning aquaculture development on the coast of Hai Phong by 2015 and aquaculture planning of Quang Ninh city, which force to reduce the number of fish cages.

- Develop the related technologies, including feed and feeding technology, artificial fingerling production, post-harvest and processing technology, and marketing will also be very important in supporting sustainable marine aquaculture development.

- Improve the awareness of farmers and tourists about the role and impact of the environment by education and training in order to enhance awareness, environmental actions and the responsibility of the farmers as well as tourists in the area.

- Collect and treat waste from fish farming and tourist activities.

4. CONCLUSION

DO concentrations in the water at Quang Ninh province and at Hai Phong city decreased significantly from 2005 to 2012. Some areas with high density fish cages such as Ben Beo, Tung Gau (Hai Phong) and Kenh Ba Men, Cua Van (Quang Ninh) often had low levels of DO in the water (<5.0 mg/l). The shortage of DO could be demonstrated by using aerators to supply oxygen to fish in fish cages at Ben Beo - Hai Phong in 2012.

Concentrations of $N\text{-}NH_4$ were the highest among dissolved inorganic nutrients in all instances. From 2008 to 2012, nutrient concentrations increased significantly, especially $N\text{-}NH_4$and $N\text{-}NO_3$. Concentrations of heavy metals (Cu, Pb, Cd, Hg) in water increased significantly from 2005 to 2012.

Although the RQtt value based on the Vietnamese environmental standards was below the environmental safety (RQtt <0.75) in both regions, localized pollution was found in areas with a high density of fish cages, such as Cua Van, Quang Ninh. Based on the ASEAN standard, the RQtt values for both areas were above the environmental safety, highlighting the risk of disaster and environmental impact on aquatic farming activities.

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