

PROPOSING SOLUTIONS TO MANAGE AND USE WATER QUALITY ZONES OF THE HA LONG BAY

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Abstract: *The Ha Long Bay has great potential in multi-objective and multi sector development, particularly famous for natural beauty and the precious heritage values that should be preserved. However, the economic and social development here has caused huge pressures on Bay environment. The study proposes water quality management solutions and reasonable use of the Bay. The solutions only focus on adjusting water use activities based on the marine spatial planning and management approach. Water quality general objective of the Bay is that the water environment must be protected and maintained so that the marine ecosystems can survive and develop normally. On this basis, the study proposes the specific goals of water quality management and water use activities which are allowed to perform, not perform or restricted in each region of the water quality.*

Key words: *coastal water quality, Ha Long Bay, water quality zoning, coastal management and usage.*

1. INTRODUCTION

The Ha Long Bay, which is located in Quang Ninh province, includes 1,969 islands and islets, forming a spectacular seascape of limestone pillars. Because of their precipitous nature, the Ha Long Bay was ranked a world natural heritage site in 1994 and recognized added geology-geomorphology value in 2000 by UNESCO. The Bay has great potential in multi-objective and multi sector development.

Since the Ha Long Bay was recognized as the world natural heritage (1994) and Ha Long city became one of the Centers of the key economic region in the North of Vietnam, social-economic activities here take place intensively, especially tourism industry, ports, marine-transport, sea products, industry and urbanization. These activities have caused the deterioration of natural resources and environmental quality. The Quang Ninh province and the Ha Long Bay Management Board have been trying to control the environment of the Bay. However, it still exists some environmental problems such as the water

quality in the coastal region is very poor (*Ha Long Bay Management Board (2013), Quang Ninh DONRE (2011)*).

This study was performed to determine criteria, management direction for water quality protection and reasonable use of the Bay. The results of this research have important signification for the process of marine spatial planning and management of the Quang Ninh province as well as other marine management tasks that the Vietnam Administration of Sea and Islands and the Vietnam Environment Administration are carried out.

2. MATERIALS AND METHODS

The proposed solution for the reasonable use and the water quality management of the Ha Long Bay is only focused on solutions to adjust the water use activities based on the marine spatial planning and management approach of IOC/UNESCO (2009). This is a "management tool" that can overcome limitations of sectorial management, help to maximum exploitation of all resources, and minimize interest conflicts between the related parties and with the environment. This management method has been successfully applied in many parts of the US, Europe, Australia, including the Great Barrier Reef (*the Great Barrier Reef Marine*

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Park Authority (2003)), which has many similarities to the Ha Long Bay. The Great Barrier Reef has 2,900 coral reefs, 900 islands and also recognized as the world natural heritage. Under this method, marine is organized for the different purposes of use and management according to water quality protection criteria. As the result, economic activities prohibited, restricted or allowed to perform are set out in order to maintain the water quality according to the proposed criteria (*ICO/UNESCO (2009)*). After zoning/planning, the sea can be "regulated" to optimize the economical and environmental benefits, depending on their functional use as well as the water quality management criteria of each region.

The water quality zones are determined based on results of water quality index (WQI) which has been developed for the Ha Long Bay as follows (*N.T.T. Nguyen, N.C. Hoi (2012)*):

$$WQI_{HL} = (q_1^{0.55} * q_2^{0.27} * q_3^{0.18})$$

in which :

q_1 : unweighted geometric mean of the sub-indices of group 1, including DO, COD, TOC, oil and grease.

$$q_1 = \prod_1^n q_i^{1/n} = (q_{DO} * q_{COD} * q_{TOC} * q_{oil})^{1/4}$$

q_2 : unweighted geometric mean of the sub-indices of group 2, including total coliform (or fecal coliform) and TSS

$$q_2 = \prod_1^n q_i^{1/n} = (q_{T.Coli} * q_{TSS})^{1/2}$$

q_3 : unweighted geometric mean of the sub-indices of group 3, including TN (or NH_4^+), TP (or PO_4^{3-}) and chlorophyll a

$$q_3 = \prod_1^n q_i^{1/n} = (q_{TN} * q_{TP} * q_{Chla})^{1/3}$$

Table 1. Water quality classification and usages

No.	WQI _{HL}	Water quality	Water use ability
1	96 - 100	Excellent	Can be used for any purpose.
2	88 - 95	Good	Can be used for any purpose, except protection of aquatic life or special aquaculture
3	63 - 87	Medium	Tourism, recreation without direct water contract, ports and navigation, industrial water supply
4	48 - 62	Bad	Ports and navigation, industrial water supply or other purposes which do not need high water quality.
5	1- 47	Very bad	Ports and navigation only

Data for zoning is the measurement data of the Ha Long Bay water quality of the Author in April 2013 and August 2013 and the water quality monitoring data of Quang Ninh DONRE and the Ha Long Bay Management Board. The Ha Long Bay water quality is divided into three zones, including (1) the good to very good water quality zones (the core zone and the seaward buffer zone of the Bay), (2) the bad to medium water quality zones (the entire Cua Luc Bay, Bai Chay and Tuan Chau areas), and (3) the very bad water quality zones (coastal strip from the Cua Luc to the Nam Cau Trang wharf, Bai Chay wharf). The specified water quality zones are shown in Figure 1.

3. RESULTS AND DISCUSSIONS

3.1. Water quality protection objectives of the Ha Long Bay

Based on the objectives, perspectives and requirements for the conservation of the Ha Long Bay in “The Ha Long Bay management regulation” (Quang Ninh provincial people's Committee (2007)) and “The resolution on the management, conservation and promotion of the world heritage value of the Ha Long Bay between 2013-2015, vision to 2020” (Quang Ninh provincial people's Council (2012)), the proposed management and protection objectives of the Ha Long Bay’s water quality as follows:

General objective: The Ha Long Bay water environment must be protected and maintained so that the marine ecosystems can survive and develop normally.

Detail objectives: The Ha Long Bay water environment must reach the National technical regulation on coastal water quality (QCVN 10: 2008/BTNMT), the marine water quality standards of ASEAN (ASEAN Secretariat (2008)) and the requirements about the water quality for the marine ecosystems. In which:

- The core zone of the Bay: The water quality must be maintained at the very good level (WQI = 95-100).

- The buffer zone of the Bay (Cua Luc Bay): The water quality must be maintained at the good to very good level (WQI = 85-94). The water quality in some wharf areas and market water areas is allowed at medium level (WQI = 60-84).

- The vicinity zone of the Bay: The water quality must be maintained at the moderate to good level

Table 2. Current water quality features and target management/protection of the Ha Long Bay

No.	Water quality zone	Current WQI	Current water quality	Target WQI	Target water quality	Note
1	The core zone	86 – 100	Good to very good	95 – 100	Very good	
2	The buffer zone	22 – 85	Very bad to good	85 – 94	Good to very good	The water quality in some wharf areas and market water areas is allowed at the medium level (WQI = 60-84)
3	The vicinity zone (Cua Luc Bay)	53 - 59	Bad	60 – 84	Medium to good	

3.2. Proposing solution for management and use of the Ha Long Bay waters

Using and extraction solutions of the waters in the Ha Long Bay is proposed on the views that water use purposes must match:

- The water quality requirements for the purpose of that use.

- Target management and protection of the water quality in each zone of the Ha Long Bay set out above.

- The characteristics of the natural environment, economy and society.

3.2.1. The good to very good water quality zones

The water quality in these zones is acceptable for aquatic cultivation and conservation according to the QCVN 10: 2008/BTNMT and marine water quality criteria of ASEAN as well as standards of other countries in the region. These regions include the core region of the Bay and the seaward buffer zone (figure 1).

In scientific term, the water quality in these

areas can cater for all usages of water. However, this is the core of the world natural heritage so that it should be preserved the status quo and not be changed the landscape, the geology, the environment, and the ecosystem (*Quang Ninh provincial people's Committee (2007)*). The management objective in these areas is that the water quality must be protected and maintained at the very good level (WQI = 100-95).

As a result, management and use orientation of these waters are to conserve, protect and restore the marine ecosystems, and to restrict the development activities that have adverse impacts on the environment in general and the water quality in particular. The water use activities and the levels of performance in these areas are proposed in table 3. The water use activities are not allowed to perform in the protected area of the Ha Long Bay, including Ga Chối islets area, Thien Long cave, Kim Quy cave, Coc Cheo islets, Tam Cung cavern, Quyt Hoi cave.

Table 3. Suggested activities in the good to very good water quality zones

No.	Water use activities	The reason proposed	Level of activity
1	Conservation, protection and restoration the marine ecosystems	In response to the conservation requirement of the natural world heritage	No restriction
2	Eco-tourism, cultural and heritage tourism	To promote the potential values of the heritage	No restriction, according to the current rules
3	Recreational tourism, water sports	To promote the potential values of the heritage	No restriction, according to the current rules
4	Marine water desalinization for human living	Serving the tourist activities and the people living on some islands and destinations	No restriction, according to the current rules
5	Cultivating sea products	This is the traditional activity of the residents on the Bay, at the same time serving ecotourism and cultural heritage tourism	Restriction, in the form of natural and extensive farming, according to the current rules
6	Fishing	This is the traditional activity of the residents on the Bay, at the same time serving ecotourism and cultural heritage tourism	The limit, in the craft form, in accordance with current rules
7	Residence on the Bay	This is the traditional activity of the residents on the Bay, at the same time serving ecotourism and cultural heritage tourism	Restriction, according to the current rules
8	Marine navigation	Serving the tourist activities and the activities of the CAI LAN port, the gasoline B12 port gasoline B12 ...	Restriction, according to the current rules
9	Research, education, and training	Catering management, conservation and use of the Bay	No restrictions, in accordance with the current rules, without changing the landscapes, the geology, the environment and the ecosystem of the Bay
10	Other limited impact activities (rescue, environmental quality monitoring and protection, video, photograph, ...)		No restrictions, in accordance with the current rules, without changing the landscapes, the geology, the environment and the ecosystem of the Bay

3.2.2. The bad to medium water quality zones

Table 4. Suggested activities in the bad to medium water quality zones

No.	Water use activities	The reason proposed	Level of activity
1	Conservation, protection and restoration the marine ecosystems	In response to the conservation requirement of the natural world heritage	No restriction
2	Tourism, recreation without direct water contract	To promote the potential values of the heritage	Restriction (only perform at points which have beautiful seascape)
3	Marine navigation	Serving the tourist activities and activities of the CAI LAN port, the gasoline B12 port gasoline B12 ...	Restriction, according to the current rules

No.	Water use activities	The reason proposed	Level of activity
4	Wharfs and small ports	Current activities	Restriction, according to the current rules
5	Research, education, and training	Catering the tasks of management, conservation and use of the Bay	No restrictions, in accordance with the current rules, without changing the landscapes, the geology, the environment and the ecosystem of the Bay
6	Other limited impact activities (rescue, environmental quality monitoring and protection, video, photograph, ...)		No restrictions, in accordance with the current rules, without changing the landscapes, the geology, the environment and the ecosystem of the Bay

These areas include the waters in the entire Cua Luc Bay (in the surrounding area), Bai Chay and Tuan Chau areas (in the buffer zone). Concentrations of nutrients, organic matter and oil there are quite high and sometimes higher than the standard value of the QCVN 10: 2008/BTNMT or the ASEAN's criteria for the beach, water sports.

To be able to restore the water quality to the good level (WQI = 85-94) in Bai Chay and Tuan Chau beaches and to the medium level (WQI = 60-84) in the Cua Luc Bay, this study proposed orientation of management, exploitation and use these areas as follows: to conserve, protect and restore the coastal ecosystems, adjust or reduce the existing development activities and implement some measures to prevent or minimise the negative impacts from these activities. The water use activities and the levels of performance in these

areas are presented in table 4.

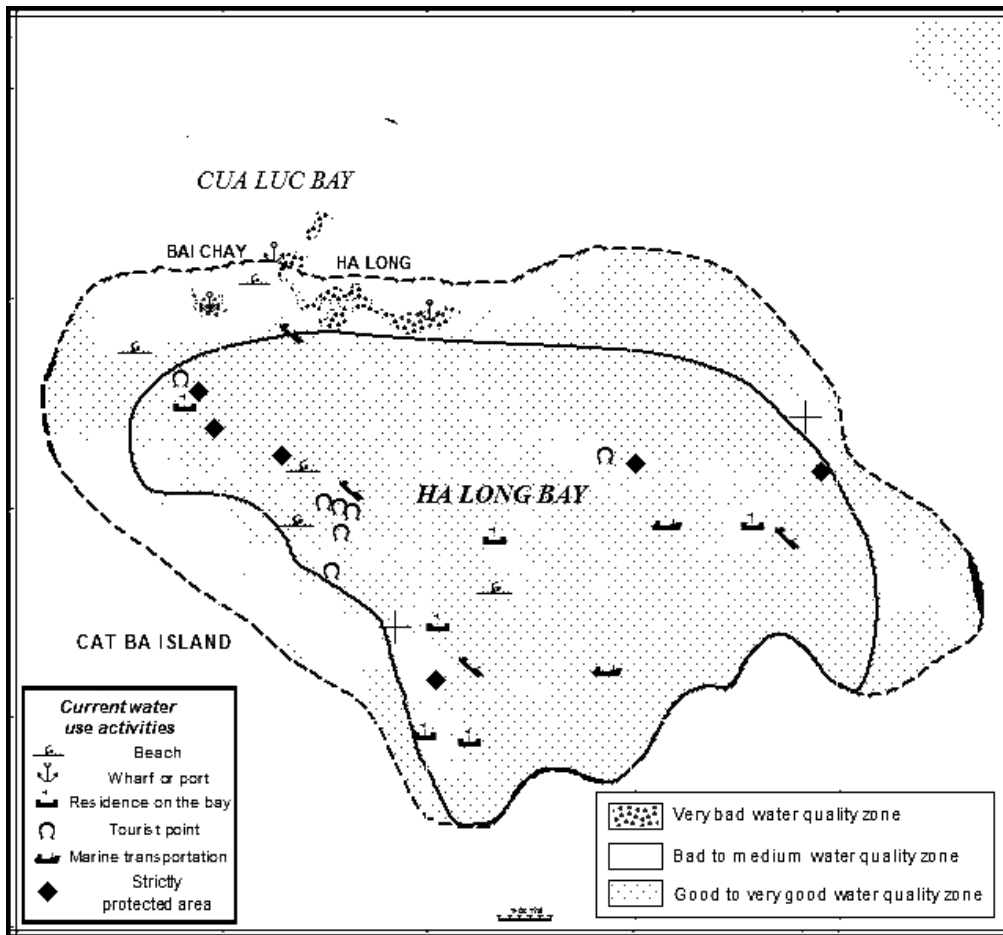
3.2.2. The very bad water quality zones

They are located primarily along the coastal strip from the Cua Luc to the Nam Cau Trang wharf and Bai Chay wharf. The water quality those are very bad due to oil, organic and nutrient pollution.

The management objective in these areas is that the water quality must be protected and maintained at the medium level (WQI = 60-84). Because the regions are located in the buffer zone of the Ha Long Bay and have very bad water quality so the orientation of management, exploitation and use these areas is to carry out immediately some measures to reduce pollution and other negative impacts of the current development activities. The water use activities and the level of performance in those areas were proposed in table 5.

Table 5. Suggested activities in the very bad water quality zones

No.	Water use activities	The reason proposed	Level of activity
1	Conservation, protection and restoration the marine ecosystems	In response to the conservation requirement of the natural world heritage	No restriction
2	Marine navigation	Serving the tourist and residential activities	Restriction, according to the current rules
3	Wharfs and small ports	Serving the tourist and residential activities	Restriction, according to the current rules
4	Research, education, and training	Catering the tasks of management, conservation and use of the Bay	No restrictions, in accordance with the current rules, without changing the landscapes, the geology, the environment and the ecosystem of the Bay
5	Other limited impact activities (rescue, environmental quality monitoring and protection, video, photograph, ...)		No restrictions, in accordance with the current rules, without changing the landscapes, the geology, the environment and the ecosystem of the Bay



No.	Suggested water use activities	Good to very good WQ zones	Bad to medium WQ zones	Very bad water quality zones
1	Conservation, protection and restoration the marine ecosystems	√	√	√
2	Eco-tourism, cultural and heritage tourism	√	√	x
3	Recreational tourism, water sports	√	x	x
4	Tourism, recreation without direct water contact	√	R	x
5	Marine water desalinization for human living	√	x	x
6	Cultivating sea products	R	x	x
7	Fishing	R	x	x
8	Residence on the Bay	R	x	x
9	Marine navigation	R	R	R
10	Wharfs and small ports	x	R	R
11	Research, education, training	√	√	√
12	Other limited impact activities (rescue, environmental quality monitoring and protection, video, photograph)	√	√	√

Figure 1. Map of water quality management and use orientation of the Ha Long Bay

Notes:

- The water use activities have to be carried out in accordance with current regulations and are not allowed to perform in the strictly protected area of Ha Long Bay.
- √ : Proper water use due to safe water quality or limited impact activities.
- x : Unproper water use due to unsafe water quality or adversely impact activities.
- R : Restricted water use due to unsafe water quality or risk of activities

4. CONCLUSIONS

Research has come up with common goal of the water quality management and use of the Ha Long Bay is that the water environment must be protected and maintained for normal development of the marine ecosystems. Consequently, the water quality in the core region of the Bay must be maintained and protected at the very good level (WQI = 95-100). The water quality of the buffer zone must be kept and protected at the good to very good level (WQI = 85-94). The average to good level (WQI = 60-84) is the water quality requirement in vicinity zone. On these bases, the activities of conservation and restoration the marine ecosystems, research, education and training, and other limited impact activities (rescue,

environmental quality monitoring and protection, video, photograph) could be performed in all water quality zones. Other water usages like tourism and recreation, water sports, marine water desalinization for human living, fishing and aquaculture, port and navigation, residence on the Bay should be allowed to perform, not perform or restricted depend on the water quality in each region of the Ha Long Bay and impact level of those activities.

5. ACKNOWLEDGEMENTS

The author group would like to thank the Ha Long Bay Management Board and the Quang Ninh DONRE for providing the figures for this study.

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BBT nhận bài: 25/10/2013

Phản biện xong: 7/11/2013