A Comparative Study on the Pollution of China-Japan Marine Environment

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Abstract

The major objective of the research is to analyze the marine environmental pollution (MEP) in China through qualitative and quantitative methods. In recent years, MEP had attracted global attention. With the rapid development of the economy, China's MEP is becoming serious, which however has not got enough scientific analysis and public attention, thus affecting the effective countermeasures. Based on the comparative analysis and case study, the research reviewed the lessons and experiences of Japan’s MEP problems, and analyzed the MEP and its main causes in China with Shandong Province as a case study. Results from this research are expected to fully understand the MEP in China and give suggestions to policy makers when coping with the challenges of MEP. The dissertation is divided into 5 chapters.

In chapter 1, the thesis briefly introduced the general definition of MEP, and conducted a literature review on the research of MEP both in China and Japan. After evaluating the previous studies relating to the MEP in China, the study pointed out the importance of immediate actions to the MEP problems in China, followed by the main objective of this research.

In chapter 2, the study firstly gave a background analysis on population and economy of the coastal provinces of China, and introduced two standards for evaluating the quality of surface water and seawater in China. According to these two standards, the study analyzed the latest situation of China’s MEP based on the data from relevant departments of Chinese government. The results imply that, although the overall situation of MEP in China is becoming better during these years, i.e. the proportion of the best class quality seawater kept growing and reached 46.1% in 2018, however, the pollution situation is still serious, with the proportion of the worst class quality seawater being 18.7% in 2018. The study further addressed the main pollution indexes of the seawater quality, such as inorganic nitrogen, active phosphate, chemical oxygen demand (COD) and petroleum pollution, etc. The effects of MEP disasters such as red tide and green tide were also discussed. As the results show, the MEP mainly comes from the flowing rivers and land sewage outlets into the sea without meeting the standards, meaning that the land pollution source control is very important to MEP. Results from this study indicate that, the MEP of four main sea areas in China (the Bohai Sea, Yellow Sea, East China Sea and South China Sea) have different characteristics. The study also co-related the situation of economy with the MEP in some typical coastal provinces and cities in China.

In chapter 3, Shandong Province in China is regarded as a typical peninsula coastal area in the case study. The thesis studied its economic structure, coastal tourism and marine industry. The results indicate that, during 2011-2015, the coal consumption of Shandong accounted for 8-11% of the total coal consumption in China. The coal-dominated energy structure had brought about much land-based pollution emissions and various challenges to the MEP of Shandong, such as large areas of green tides and red tides, greatly affecting the swimming beaches during the tourist seasons. The study also adopted some qualitative method like in-depth interview to analyze the complex views within different local stakeholders, the analysis proved that their understanding of MEP was much different. Through this case study, the research provided a further understanding of MEP in China.

In chapter 4, the thesis gave a comparative study on MEP between China and Japan, mainly compared and analyzed the government's marine management mechanisms and the implementation of marine environment laws, plans, related standards, and public participation with respect to MEP. This comparative study suggests that, as a traditional marine country, Japan has a relatively strong national-level coordination mechanism on MEP, which can promote the policies, regulations and standards to be implemented well. On the other hand, China is lack of integration and coordination when facing the MEP problems, and China can benefit a lot from Japan’s lessons and experiences in MEP.

In chapter 5, the study gave conclusions and pointed out the future research directions. These conclusions are helpful in the aspect of policy making on MEP in China. And the study also summarized some useful recommendations on relevant regulations and standards.

Results from this work imply that, with the economy development in of China, the MEP problem is facing serious challenges, which has not been paid enough attention by Chinese government and the public. The study analyzed the latest situation of MEP in China, and claimed that the land-based pollutants are the main sources of MEP in China. Thus the environmental pollution problems for sea and land need to be considered as a whole system to deal with. Taking Japan as a reference, the study further put forward policy recommendations for China's MEP, which are expected to have potentially practical values for Chinese government to cope with the challenges of MEP problems.

Keywords: Marine environment pollution, China, Japan, Standard, Policy

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Chapter 1 Introduction

1.1 Overview

The ocean of the earth is covering 140 million square miles, about 72% of the earth's surface (UN, 2017). The ocean is an important ecosystem as the prime source of nourishment for the life, and also is important for trade and commerce. Ocean makes people apart in several separated continent and many islands. Most of the world's people live in the area of no more than 200 miles from the sea (UN, 2017), therefore, the ocean is very important to humans.

According to United Nation, the marine environment pollution (MEP) is the pollution introduction by man, directly or indirectly, of substances or energy into the marine environment, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities (UN, 1982).

Marine Environment and MEP is an important issue, people pay much attention on protection of marine environment. The United Nations Environment Programme (UNEP) tries to lead protecting oceans and seas, to realize and promote the environmentally use of marine resources. The Regional Seas Conventions and Action Plans is the world's only legal framework for protecting the ocean at the regional level. UNEP issued The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, it is the only global intergovernmental mechanism directly addressing the connectivity between terrestrial, freshwater, coastal and marine ecosystems (UN, 2017).

The United Nations Educational, Scientific and Cultural Organization (UNESCO), through its Inter-governmental Oceanographic Commission (IOC), coordinate items in marine research, observation systems, hazard mitigation and better managing ocean and coastal areas (IOC-UNESCO, 2018). The International Maritime Organization (IMO) is also the key United Nations Institution for the implementation of international marine law, its main task is to set up a mechanism for the marine industry (IMO, 2018).

1.2 Literature review

MEP is a complex and interdisciplinary subject, scholars try to find proper methods and resolutions for studying it (Christie, 2011), and creating space for interdisciplinary marine and coastal research. Recently, many issues on MEP had drawn much attention, such as the marine plastic waste pollution (Lebreton et al, 2018; Worm et al, 2017).

Both China and Japan pay much attention on utilization of marine space and resources, researched on MEP had also been carried out in many fields in these two countries.

1.2.1 Literature review focus on MEP in China

Researchers study on the development of marine resources utilization and marine industry (Dong et al. 2005). A few of studies focus on the relationship between the economic growth and MEP in China (Cao et al, 2007; Xie and Yu, 2007; Chen and Li, 2015; Ji et al, 2012; Zhang and Wen, 2008; Wang, 2013; He et al, 2014; Chen and Li, 2015), but the existed studies generally lack of international perspectives. Past researches focus on MEP in China can be divided 2 fields: theoretical and empirical studies in key sea areas.

(1) Theoretical research

Faced with the reality between the coordination of China's economic development and the marine environment, some researchers (Zhang and Wen, 2008) developed theoretical and quantitative analysis model for the sustainable development of the marine economy, exploring the relationship between economic development and the marine environment. Facing the rapid growing of China economy, some researchers analyze and provide prejudgment that the marine economy will become a new growth pole for economic development (Wang et al., 2014). For the fundamental topic of the relationship between economic development and MEP, some researchers had proved that, the development of the marine economy will inevitably lead to the deterioration of the marine environment (Wang, 2013). These theoretical studies provided basic thinking paths for exploring the MEP problems. However, most of these studies are focused on China's MEP problems themselves, and there is still lack of research from international perspectives.

(2) Key sea area research

In China's vast coastal areas, the challenges of MEP had become increasingly prominent, and existed research work MEP are mostly around China's coastal areas.

The first scale is the study of the interactive relationship between economic development and MEP in the entire eastern coastal region of China, focus on the interplay between economic growth and MEP (Wang, 2013). From multiple perspectives, these empirical studies had verified the excessive growth of the coastal economy (especially industry) had indeed brought different degrees of pollution to the marine (especially offshore) ecosystem.

Besides China's coastal areas, many researchers paid much attention on the specific sea area of China and coastal economic zone, such as the study in Pearl River Delta, economic layout and marine ecological relationship (Wang, 2011), research on land use evolution of coastal city Zhuhai, study on the impact of land reclamation on the marine ecological environment (Dou, 1994).

Scholars studied the economic development and environmental pollution of coastal cities in the Yangtze River Delta, such as the environmental pollution of 72 industrial districts in Shanghai (Dou, 1989), Yangtze River Delta marine economy and ecological protection (Ye, 2006).

Studies in Bohai Rim of China include: the study of MEP in Bohai Rim (Piao et al., 2009), research on the green tide disaster of east Shandong Peninsula (Song et al., 2007), the relationship between tourism development and the marine environment in Beijing-Tianjin-Hebei Region (Dou, 2016).

These extensive empirical studies on MEP of China's coastal areas had confirmed various types of pollution problems. However, how to find out the countermeasures to control and stop the deterioration of China's MEP, there is still lack of in-depth research.

(3) Evaluation of existing research

The existing researches on China's MEP covered many topics. However, facing the rapid development of China's economy, the analysis on the latest situation of the MEP situation in China is needed. To better understand China's MEP problems and finding proper countermeasures, an international perspective is helpful, especially the lessons and experiences of other countries on MEP. Moreover, the links between scientific research and policy formulation should be paid more attention.

1.2.2 Literature review focus on MEP in Japan

(1) History and evolution of MEP in Japan

Since Meiji Restoration in 1868, Japan began its industrial revolution. In 1880s, Japan already faced the problem of water and soil pollution, the Ashio Copper Poison case around 1890 was taking as the first environmental pollution incident (Notehelfer, 1975). Besides the Ashio Cooper Poison case, there are several environmental pollution cases before the World War II, such as the Osaka Alkali Company case around 1900 (Kabashima, 2012). During that period, the Japanese government put the primary emphasis on industrial development, environment pollution did not be paid enough attention.

After the World War II, Japan had experienced very fast economic development. The average annual growth rate of GNP is 9.2% during the first decade after the war (1946-1955) when the economy recovered from the war. Japan kept the same rate until mid-1970s (1956-1973) which is the period of the high economic growth. The output of industry increased from 2276 billion Yen in 1950 to 127521 billion Yen in 1975, while the percentage of heavy industry increased from 41.6% to 61.0% under the "Priority Production Scheme" (PPS), which invested more on basic intermediate goods such as steel and coal (Sadahiro, 1991).

The fast industry development and PPS policy caused serious industrial pollution which had disastrous effects on human health, such as the famous “big four pollution cases”. Among the environmental disasters, the Minamata disease is the typical case related MEP. The Minamata disease was first reported in Minamata in Kumamoto Prefecture in 1956, and identified as a heavy metal poisoning, specifically methylmercury poisoning, transmitted by the ingestion of contaminated fish from Minamata Bay. The methylmercury, through the contaminated fish, attacked the afflicted patient’s central nervous system, which caused a variety of symptoms, including numbing in the arms and legs, impairment of balance, ringing in the ears or loss of hearing, tunnel vision, and decrease in communication skills (Kawashima, 1995).

Pushed by citizens’ protests and realized that industrial pollution is the key reason for the damage of human health, the government of Japan was forced to confront pollution and made noteworthy advances in environmental protection. The Diet (64th Diet, known as Pollution Diet) passed 14 environmental laws to control pollution around 1970 (Edahiro, 2009). Japan became the first nation in the world to provide criminal sanctions for acts of pollution that endanger human health (Kondrat, 2000). The Basic Law for Environmental Pollution Control, which is the first comprehensive, nationwide environmental pollution control law in Japan, was enacted in 1967, and amended in 1970. The Water Pollution Control Law, the Law relating to the Prevention of MEP and Maritime Disaster were also enacted in 1970, Law concerning Special Measures for Conservation of the Environment of the Seto Inland Sea was enacted in 1973.

Since 1970, Japan made considerable progress in solving problems related to air, water pollution and the handling of wastes. Japan became a successful example in decoupling of economic growth from emissions of industrial wastes, especially air pollution, as well as an example that environmental policies and economic development can be mutually supportive. The MEP had also been concerned and treated, especially in coastal water, such as Seto Inland Sea (Tsuneo, 1984).

After the so-called “Lost Decade” of the 1990s (sluggish economic growth), a prolonged period of economic stagnation and deflationary pressures, Japan began to recover in the early 2000s, driven by its exports. In late 2009, the government adopted a New Growth Strategy that identified environment and green innovation as two of the key drivers of future growth and job creation (Jones and Yoo, 2011).

(2) Enlightenment from Japan's experience on MEP

The lessons and experience from Japan’s MEP can be taken as a reference and provide suggestions for China, who is facing various environment problem during its rapid economic development. Literature study of Japan's economic development and MEP shows that, the development strategy of “economic priority and environmental lag” is wrong. The industrial structure can affect MEP, environmental pollution incidents may seriously endanger human health, and the understanding and governance of MEP will take a certain period of time with a high cost. So, the sustainable development strategy that coordinate economic development and environmental protection should be adopted.

1.3 Focus, importance and value of the research

Considering MEP is an interdisciplinary complexity issue, this research mainly focuses on the MEP problems of China during its rapid economic development, and selecting coastal Shandong Province as a case study for in-depth analysis.

The research also targets on comparing the marine environmental issues between China and Japan. Japan's MEP appeared earlier than China, Japan had accumulated a lot of experiences in fighting with MEP. China can learn from Japan's experience and explore its own systematic countermeasures to deal with MEP problems.

The study also aims to bridge the gap between scientific research and policy making, trying to face the practical problems of MEP in China, provide suggestions and policy recommendations, and call for public attention and immediate action to deal with MEP in China.

1.4 Thesis structure

The structure of the thesis is mainly as following:

The first part based on a brief introduction to the definition of the marine environment, and literature review on the relationship between economic development and the marine environment both in China and Japan. Mainly focused on the researches related to the relationship between the rapid economic growth of the Chinese economy and marine environment.

The second part based on the data published by relevant departments of the Chinese government, including data on economic development and marine environmental pollution, try to analyze the latest situation of China’s coastal economy and marine environment. The analysis pay attention to the overall situation of China's coastal areas, as well as the four sea areas of China, the Bohai area, the Yellow Sea area, the East China Sea area and South China Sea Area. Based on the data of coastal provinces and typical cities, the research also analyzes the situation of economy and marine environment in coastal areas, including the current situation of China's marine environment quality, the main causes of marine environmental pollution, the main types of land-based pollution and its main pollution indicators.

The third part is the case study on Shandong Province which is regarded as a typical peninsula coastal area in China. The thesis analyzed its economic structure, coastal tourism and marine industry. The results indicate that the coal-dominated energy structure had brought land-based pollution emissions and various challenges to the MEP, such as large areas of green tides and red tides, greatly affecting the swimming beaches during the tourist seasons. The study also adopted qualitative research method to analyze the complex views of different local stakeholders. Through this case study, the study provided a further understanding of MEP in China.

The fourth part gave a comparative study on China and Japan. It mainly compared and analyzed government's marine environmental management mechanism, administration of ocean management, the formulation and implementation of marine environment laws, marine environmental plans and their implementation, related standards and implementation, and public participation. The research highlighted the lessons and experiences that China can learn from Japan.

The fifth part is the conclusion drawn from above analysis and the suggestions to policy making based on the research findings.

1.5 Data and Methods

1.5.1 Data

(1) Data on MEP in China

Data on MEP in China are collected from the published year book of China's government, such as Marine Administration of China (MAC), Ministry of Ecology and Environment of China (MEEC) and other related agencies. The data are mainly as following: marine ecological monitoring data, red-tide disaster monitoring data, and data related to marine pollution, ecology, environment, risk, etc.

MEEC set up a national Coastal Marine Environmental Monitoring Network (CMEMN), which release official data on marine environment of China. This network consists of hundreds of offshore water quality monitoring points, monitoring about China's rivers into the sea, and select sources of pollution directly discharged into the ocean. This network also selects some important marine spaces regions to be monitored, including bathing beaches, estuarine sediments of rivers, marine biodiversity, typical marine ecosystems, marine protected areas, coastal wetlands, fishery waters, etc., and released corresponding monitored data.

(2) Data on economy in China

Data on economy in China are collected from China Statistic Yearbook on economy and society development, the data include population, gross domestic production (GDP). The marine industry data are collected from Marine Economy Bulletins, include shipbuilding industry, coastal tourism, marine salt industry, fisheries, etc.

1.5.2 Standards related to MEP

The standard for MEP evaluation includes the water quality evaluation standards from China and Japan.

The water quality of rivers entering the sea of China refers to the “Surface Water Environmental Quality Standards” (GB3838-2002), Class I as the best, Class V as the worst. The key information of the standard is listed in Appendix 1.

The coastal water quality of China refers to the "Sea Water Quality Standards" (GB3097-1997), Class I as the best, inferior Class IV as the worst, and class II is used as the standard of compliance, detailed information is listed in Appendix 2.

In the comparative study, the related Japanese water quality standards were also taken as references.

1.5.3 Research methods

The research employed qualitative analysis and quantitative analysis, taking Shandong as case study, and gave comparative study between China and Japan. The quantitative analysis was applied in analyzing the development of China's coastal economy, industrial structure and marine industry, as well as the water quality evaluation. The qualitative analysis collected information from in-depth interviews with different stakeholders (governmental organizations, civil society, private sector, etc.), as a more deliberative, reflexive, and multidimensional approach facing different MEP perspectives. Case study of Shandong can further prove the situation of China's coastal MEP and its relationship with energy structure and economic development.

Comparative study between China and Japan can provide useful reference for China's MEP policy recommendations.

Chapter 2 Analysis on China's MEP

2.1 Introduction

2.1.1 Background of China

China is located in East Asia, on the west coast of the Pacific Ocean. The land area of China is about 9.6 million km^2, the coastline of the eastern and southern continents is more than 18,000 km, and the water area of the inland sea and the frontier sea is about 4.7 million km^2. There are more than 7,600 large and small islands in the sea area of China. The provincial administrative districts are divided into 4 municipalities, 23 provinces, 5 autonomous regions, 2 special administrative regions. By the end of 2018, the total population of mainland China (including 31 provinces, autonomous regions, and municipalities) was 1.395 billion, an increase of 5.30 million compared with 2017 (CSC, 2019).

China's economy has developed very fast compared with other countries. China's GDP accounted for 3.65% in the world in 2000, and increased to 15.12% in 2017, while the US accounted for 30.91% in 2000 and decreased to 23.90% in 2017, Japan decreased from 14.69% to 6.03%, as shown in Table 2-1.

2.1.2 China's coastal areas

Along the eastern and southern continental coastlines of China, there are 5 main sea areas: Bohai Sea, Yellow Sea, East China Sea, South China Sea and the sea area east of Taiwan. There are 11 provincial-level regions in coastal China, including 8 provinces, 1 autonomous region, and 2 municipalities, all these regions are the core region of the China national economy.

Because China's growing economy is increasingly concentrated in coastal area, people are gradually migrating to the coastal regions. According to data released by the National Bureau of Statistics (NBS) of China, the total population of China increased from 1.27 billion in 2000 to 1.34 billion in 2010, and reached 1.40 billion in 2018, while the population of 11 coastal provinces (autonomous regions and municipalities) increased from 520.73 in 2000 million to 576.88 in 2010 million, and reached 608.81 million in 2018. The coastal region attracted more migrants because of the job opportunity, the proportion of population in coastal provinces increased from 41.1% in 2000 to 43.0% in 2010, and reached 43.6% in 2018, as shown in Figure 2-1.

There are 2 provinces in China with over 100 million population in 2018. Guangdong province which has a population of 113.46 million, followed by Shandong with 100.47 million population. Due to the relatively fast economic development, most of coastal provinces experienced a growth of population and the increased proportion in China. The proportion of population in Guangdong increased from 6.8% in 2000 to 8.1% in 2018, as shown in Figure 2-2.

Rapid economic growth and increase in population brought negative impacts on MEP, the environment of China’s coastal areas faced more pressures.

2.2 Economic development in China's coastal areas

Since 1997, the total economic output of 11 provinces along the coast of China accounted for more than half of the national total. China's coastal areas have become the core region of the national economy.

2.2.1 Economy of coastal provinces in China

(1) Basic situation

The proportion of GDP of 11 coastal provinces in China is above 50%, and reached 60% around 2005, as shown in Figure 2-3.

(2) The GDP of 3 main economic zones in China

China's 3 major economic regions are concentrated in the coastal areas: the Yangtze River Delta with Shanghai as the center, the Bohai Rim economic region including Tianjin, Shandong, Liaoning and Hebei provinces, and the Pearl River Delta with Guangdong as the center. The development of these three economic regions largely represents the highest level of China's economic development, and they are leading the course of China’s modernization. The GDP of 3 main coastal economic zones account for 50% of the country.

The economic output of the Yangtze River Delta and Bohai Rim, each account for about 20% of China's GDP. As the main region of the Pearl River Delta, the GDP of Guangdong Province accounted for more than 10% of the China, as shown in Figure 2-4 and Figure 2-5.

The Bohai Sea is located in the northern part of China's eastern coast. Bohai Rim economic region is the economic center of northern China with high industry and population density. It is the gateway to the world in the northern part of China as the important portal area. The Bohai Rim economic region refers to the coastal economic zone with Tianjin, Hebei, Liaodong Peninsula and Shandong Peninsula surrounded.

The Yangtze River Delta is close to the East China Sea and is located at the exit of China's largest river, the Yangtze River. The Yangtze River Delta urban agglomeration is the region with the highest degree of urbanization, the most densely distributed cities and the highest level of economic development in China. The Yangtze River Delta Economic Circle is centered on

Shanghai, with Nanjing and Hangzhou as sub-centers. The economic aggregate of the Yangtze River Delta has been standing at around 20% of China's GDP.

Facing the South China Sea, the Pearl River Delta is located at the exit of the Pearl River. It has developed water and land transportation and convenient overseas contacts. It is an important gateway to the world in the south of China. By strengthening cooperation with Hong Kong and Macao, two special administrative regions, as the core region of the Pearl River Delta, Guangdong become China's most dynamic and fastest-growing region, with a province's GDP accounting for more than 10% of the country.

2.2.2 Development of marine industry and MEP in China

Marine industries targets on marine resources and marine space. By utilizing and protect various resources of the oceans, various marine industries in China had developed quickly recent years. Since marine industry is based on the direct and regular use of marine resources and ocean space, the impact of marine industry on the marine environment is also more pronounced in many respects. So, MEP is not only affected by land-based pollution, but also received pollution directly from the marine industry.

Marine industry output is near 10% of China’s GDP from 2008-2017, as shown in Figure 2-6. According to the data released by the State Oceanic Administration (SOC) of China in year 2017, the ocean industry accounts for 9.4% of China’s GDP. As for the structure of China marine industry, coastal tourism (46.1%), transportation (19.9%) and fishing (14.7%) are the top 3 among all the marine industries in 2017. The rapid growth of the marine industry was shown in Table 2-2.

2.2.3 Coastal tourism as marine industry in China

Coastal tourism includes all tourism and leisure activities in coastal areas and offshore waters. As tourism is an important part of the development of the marine industry, the relationship between coastal tourism and MEP is increasingly considered in marine policy. In many countries and regions, coastal tourism is the largest among the marine industry, for example, in China, coastal tourism accounts for more than 50% of the marine industry. However, various MEP problems may directly or indirectly affect coastal tourism. A good environment (including clean water, sand, wetlands, and marine life and coastal habitats) is one of the important attractions of coastal tourism, on the contrary, red tides, green tides and other MEP problems will bring serious challenges to coastal tourism, as shown in Figure 2-7.

2.3 Analysis on MEP of China

Although China's overall quality of marine environmental seems to be improved in recent years, however, the status of MEP is still serious. For specific situations around the vast coastal areas, to coordinate the development of economy and MEP need to increase the investment in marine environmental protection, strengthening environmental law enforcement and adopt more advanced technology. The impact of economic development to MEP is much serious in coastal areas of China.

2.3.1 Indicators and data

According to the official data released by Chinese government, China monitored more than 300,000 square kilometers of marine environment near the coast. The data of this study mostly use near-shore monitoring data.

There are many evaluation indicators for marine environmental pollution, this study analyzes China's MEP based on the following data: seawater environmental quality, major coastal pollutants, water quality of rivers that get into the sea, and marine environmental disasters.

Data from the “The Environmental Quality of China's Coastal Waters” is jointly monitored and released by the following departments in China: Ministry of Ecology and Environment (MEE), Ministry of Agriculture & Rural Affairs, Ministry of Transport.

In 2016, China's Coastal Marine Environmental Monitoring Network (CCMEMN) water quality monitoring includes: 417 offshore water quality monitoring points, 192 rivers into the sea, 419 direct sources of pollution with a daily discharge of more than 100m^3, 27 bathing beach. The proportion of seawater quality levels is calculated primarily by the number of points monitored.

In 2018, according to Bulletin of China Marine Ecological Environmental Status by MEE, China monitored the following MEP data: 1649 marine environmental monitoring points established and controlled by the state, sections of 194 rivers into the sea, 453 sources of pollution that directly discharge into the ocean more than 100 m^3 daily, 36 beaches, 1705 biodiversity sites, 21 typical marine ecosystems, 89 marine protected areas, 24 coastal wetlands, and 48 important fishery waters. In addition, sediment quality monitoring was carried out on some important estuaries.

2.3.2 Analysis of coastal seawater quality of China

(1) Overall analysis

According to the national standard “Seawater Quality Standards” issued by China (GB 3097-1997), seawater quality is divided into 4 classes according to different functions and protection objectives of the sea area[1]. Class I is the best, Class IV is the worst. In the practical situation, due to many test results even can’t arrive the lowest level Class VI, so, the evaluation system added “Inferior Class IV”,

In recent years, China's seawater quality had gradually improved, which shows that the momentum of China's MEP started to be controlled gradually. Affected by various factors, the results of water quality monitoring in China's offshore waters showed great changes. However, from the general trend, the quality of offshore seawater was gradually improved, and the proportion of Class I seawater increases from 13.4% in 2001 to 46.1% in 2018; the proportion of Class IV seawater decreased from 11.9% in 2001 to 3.1% in 2018; especially for monitoring of the worst quality Inferior Class IV seawater quality had special meaning, the proportion dropped from 34.5% in 2001 to 15.6% in 2018, indicating that China had paid much attention to the problem of offshore marine environmental pollution and adopted corresponding measures to promote the gradual improvement of the offshore marine environment, as shown in Table 2-3.

(2) The MEP of coastal seawater in China

The coastal seawater pollution in China is still serious. Analysis of China's offshore seawater quality from 2001 to 2018 shows that, from 2001 to 2004, the proportion of Class I seawater quality, which is the best quality, was lower than that of the worst-quality (inferior IV class) seawater quality. Since 2005, the proportion of the Class I seawater s begun to be higher than that of Inferior Class IV. However, the proportion of the worst-class (Inferior Class IV + Class IV) of seawater is still about 20%, the MEP of coastal seawater in China is still serious, and the task of strengthening governance and management is very arduous.

(3) MEP of coastal seawaters in China’s 4 main sea areas

Analyzing the MEP of coastal seawaters in China’s 4 main sea areas in 2016 and 2017 as shown in Figure 2-8.

East China Sea：The MEP in East China Sea is the most serious among the 4 main sea areas of China, the proportion of seawater quality that meet Class I standard is only 12.4% in 2016, but the proportion of seawater quality under Class IV is more than one-third, this is partly because of rapid economic growth in the Yangtze River Delta.

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[1] Class I: adapt to marine fisheries waters, marine nature reserves and cherish endangered marine life reserves.
Class II: adapted to aquaculture areas, bathing beaches, marine sports or recreational areas where the human body is in direct contact with sea water, and industrial water areas directly related to human consumption.
Class III adapt to the general industrial water area, coastal scenic tourist area.
Class IV: adapted to marine port waters, marine development operations.

Bohai Sea: The situation in Bohai Sea area is also not to be optimism, the ration of polluted water Class IV growing from 4.9% in 2016 to 7.4% in 2017, and the ratio of below Class IV growing from 4.9% in 2016 to 9.9% in 2017. But for the clear water of Class I, the ratio dropped from 28.4% in 2016 to 19.8% in 2017, this is a warning of the deterioration trend of seawater quality. As the inland sea of China, its marine environment is not conducive to the rapid spread of pollutants. Now, Bohai Rim is the industrial center of northern China, the pollution of the Bohai Sea area is facing great challenge and should be paid special preventive solution.

South China Sea: As a more open and wide seawater area, which is relatively conducive to the discharge of pollutants. However, the environment in South China Sea seems to be beginning to deteriorate. In 2016, there is no Inferior Class IV seawater were detected, however, in 2017, it was monitored that the proportion of the Inferior Class IV seawater had reached 15.2%, which related to the rapid economic development of the Pearl River Delta, and it is need to pay much attention on the situation in the future.

Yellow Sea: The MEP in Yellow Sea appears to be the best among the 4 sea areas. In 2016 and 2017, the ratio of Inferior Class IV is 1% and 2%, the ratio of Class I is 38% and 37%.

(4) Seawater quality in coastal waters of 11 coastal provinces in China

In 2016, through the results of seawater quality monitoring in 11 coastal provinces, there is a direct causal relationship between economic development intensity and marine environmental pollution.

Among the coastal provinces, the water quality in the coastal waters of Guangxi and Hainan is excellent, and the ratio of good points detected are 95.7% and 100%. The water quality in Liaoning and Shandong is followed Guangxi and Hainan, the ratio of good points detected are 83.3% and 93.8%; For Hebei, Tianjin, Jiangsu, Fujian and Guangdong, the MEP become serious, the ratio of good points detected is 76.9%, 33.3%, 68.2%, 72.3% and 78.9%; the water quality in Shanghai and Zhejiang is extremely poor, there is no good point in Shanghai, and the good point ratios of Zhejiang is only 28.6%.

Shanghai and Zhejiang, with relatively fast economic growth, their offshore areas had been mostly polluted, followed by Tianjin and Guangdong. For example, Shanghai, as China's largest industrial city, the proportion of seawater quality that under the Inferior Class IV exceeds 70%, which is the most serious situation of seawater pollution in all provinces. Secondly, Zhejiang Province, where industrial development is also intensive and private enterprises are developed, the proportion of seawater quality below Inferior Class IV is over 50%. With the relatively lower industrialized provinces of Hainan and Guangxi, the quality of seawater still maintains a fairly good level. Hainan Province had proposed and implemented the development strategy of building an international tourist island in recent years, protecting the good island and coastal ecological environment is extremely important for tourism, the protection of its marine environment should deserve special attention, as shown in Table 2-4.

In order to further explain the pollution situation of seawater quality in coastal areas of each province, analyzing the monitoring results seawater quality that under class IV is much clear. Shanghai and Zhejiang, where economic growth is relatively fast, there offshore areas had been mostly polluted, followed by Tianjin and Guangdong. The number of provinces that had been detected Class IV seawater quality keeps increasing these years, only Hainan province had not been monitored Class IV seawater, as shown in Table 2-5.

(5) MEP in China coastal cities

The monitoring of coastal seawater quality in coastal cities also reflects the dangers of industrial development to MEP. In 2016, among the 61 coastal cities that were included in China's MEP monitoring system, the coastal seawaters quality of Shanghai, Ningbo, Jiaxing, Zhoushan, Cangzhou and Shenzhen were evaluated as “very poor”. Among them, Ningbo, Jiaxing and Zhoushan are cities of Zhejiang Province, they are the fastest growing urban agglomerations in recent years, together with Shanghai, they constitute the Yangtze River Delta urban agglomeration, which cause the direct source of pollution to East China Sea; Cangzhou belongs to Hebei Province, located in Bohai Rim region, it is a typical chemical industry city, air pollution and industrial wastewater discharge are very serious. Shenzhen, its GDP had surpassed Guangzhou in recent years, ranking first in Guangdong Province, in the ranking of the total economic output of all cities in China, according to 2017 data, Shenzhen is the 3rd largest GDP city in China, only behind Shanghai and Beijing, as a result, Shenzhen's offshore seawater pollution is also becoming serious, this is the alarm to the sustainable development of Shenzhen.

In 2018, by China's MEP monitoring system, the coastal seawaters quality of Shanghai, Jiaxing, Zhoushan, and Shenzhen were still evaluated as “very poor”, and add other 4 new cities who arrived “very poor” situation unfortunately, they are Weifang of Shandong, Panjin of Liaoning, Zhongshan and Zhuhai of Guangdong.

2.3.3 Major over-standard pollutants in China coastal waters

The main over-standard indexes in China's coastal waters include inorganic nitrogen (IN) and active phosphate (AP), organic pollutants include COD, petroleum pollution, etc. Heavy metal ions mainly include lead, copper, mercury and cadmium.

(1) Major seawater over-standard pollutants

The main pollution indicators affecting the water quality of the coastal waters as shown in Table 2-6.

IN is as the main over-standard indicator in China's offshore waters, according to the data of 2001, the ratio of over-standard pointes detected is 67.9%, this means there are two-thirds of the sea areas detected IN in 2001. In 2017, the monitored data is 30.2%, situation becomes better, but there are still near one-third of the sea areas had been monitored IN index exceeded standards. Pollution caused by IN also has some significant impact, monitoring in recent years had shown that, the increase of IN concentration in coastal waters may one of the main reasons for the occurrence of red tide disasters.

For the indicator of AP, according to the data of 2001, the ratio of over-standard pointes detected is 59.9%. For the monitored data of 2017, it is 7.0%, compared with 2001, there had been a significant decline, indicating that the governance of these two pollutant indicators had achieved certain results. China's coastal areas are highly industrialized and agriculturally intensive and developed regions, and excessive phosphorus emissions from agricultural and industrial wastewaters can lead to increased concentrations of AP in the estuary and nearshore, which can lead to eutrophication of seawater, this will bring to phytoplankton breeds abnormally, causing marine disasters such as red tides.

Among the organic pollutants, the oil pollution is relatively serious, the ratio of over standard pointes detected is 18% in 2001, and in 2017 it declined to 7.0%, situation keeps becoming better.

In the case of heavy metal ion pollution, the ratio of lead over-standard pointes detected had been 62.9% in 2001, through continuous governance and treatment, it had not been detected in 2017.

(2) Analysis of over-standard indexes for coastal water quality in different areas

In 2016, over-standard indexes for coastal water quality in 4 main sea areas as shown in Table 2-7.

- Analysis of IN

In the 4 main sea areas of China, the ratio of IN over-standard points detected in the East China Sea has the highest ratio as 55.8%; followed by the Bohai Sea, the ratio is 19.8%; Yellow Sea and South China Sea is 9.9% and 6.8% respectively.

Among the coastal provinces, the ratio of IN over-standard points detected in Shanghai is 100%, followed by Zhejiang is 71.4%. Among the coastal cities, Jiaxing, Cangzhou, Ningbo, Taizhou, Zhoushan, Shenzhen, Jinzhou, Tianjin, Nantong and Wenzhou, the ratio of IN over-standard points detected of all above cities exceeded 50%. These cities are mainly concentrated in the Yangtze River Delta, the Pearl River Delta and the Bohai Rim where the industry are concentrated areas.

- Analysis of AP

In 2016, the average ratio of AP over-standard points detected in China's offshore areas was 10.1%r. The over-standard areas are mainly concentrated in the Yangtze River estuary, the Pearl River Estuary, and some coastal waters in Jiangsu and Zhejiang. The highest value detected appeared in the coastal waters of Shenzhen, which is 5.7 times higher than the Class II value by China seawater quality standard.

In the four sea areas, the ratio of AP over-standard points detected in East China Sea is the highest as 27.4%; followed by South China Sea is 5.3%; Bohai Sea and the Yellow Sea is 1.2% and 3.3%, respectively.

Among the coastal provinces, the highest ratio of AP over-standard points detected is Shanghai as 60.0%, followed by Zhejiang as 39.3%.

Among the coastal cities, the ratio of AP over-standard points detected in Jiaxing, Shenzhen and Ningbo are higher than 50%.

(3) Other over-standard indexes in China's offshore waters

According to the 2016 monitoring data, in addition to IN and AP which were found in all coastal regions of China as main over-standard factors, in some specific areas, other over-standard indexes also had been monitored as following:

pH: ratio of pH over-standard points detected is 2.6%, the over-standard points appeared in the coastal waters of Shenzhen, Zhanjiang, Yangjiang, Qinzhou and Dongying;

petroleum: ratio of petroleum over-standard points detected is 2.2%, the over-standard points appeared in the coastal waters of Shenzhen, Chaozhou, Dongying and Tianjin;

anionic surfactants, sulfides, dichlorodiphenyltrichloroethane(DDT), COD, BOD, lead, copper, zinc, non-ionic ammonia and volatile phenols: all these indicators only have a low ratio of over-standard points detected, and the phenomenon of exceeding the standard only occurs in the coastal waters of individual cities.

2.3.4 Water quality analysis of rivers entering the sea

The water quality assessment of the rivers entering the sea refers to the "Surface Water Environmental Quality Standards" of China (GB3838-2002), following this standard, river water quality is divided into 5 classes (Class I is the best, and Class V as the worst). In the practical test, due to many test results even can’t arrive the lowest level Class V, so, the evaluation system added “Inferior Class V”.

(1) Water quality analysis of rivers entering the sea

From the monitoring results by MEE of China from 2011 to 2018, in the monitored rivers, almost no Class I water quality standards had been met. The best case was Class II water quality, and the proportion of Class III water was about one-third of the all Classes. Now, Class I to

Class III are regarded as the compliance to standard, at present, the discharge of rivers into the sea is less than 50% that meet Class III, indicating that, pollutants from rivers into the sea is one of the important sources of MEP.

In 2018, water quality monitoring was carried out on 194 rivers sections in China. Among the 194 river monitoring sections, there is no Class I water quality section; the proportion of class II water quality sections with better water quality is higher than that of 2017, as the worst water quality of inferior class V, the proportion of water quality sections had decreased compared with, as shown in Table 2-8.

(2) Water quality analysis of rivers entering the sea in 4 main sea areas of China

Among the 4 main sea areas in China, the water pollution of the Bohai Sea is the most serious, the ratio of inferior Class V and Class V is more than 50%, seawater quality of the Yellow Sea's is also serious. The situation in South China Sea and East China Sea are relatively good, as shown in Table 2-9.

(3) Water quality analysis of rivers entering the sea in coastal cities of China

The water quality of rivers entering the sea depends largely on the intensity and capacity of the environmental management by coastal cities, as shown in Table 2-10. Two cities deserve special attention, Shanghai and Tianjin, they are both important industrial cities in China, and are also densely populated megacities, and they have large amount of industrial wastewater and domestic sewage. As a coastal city, Huangpu River in Shanghai and Haihe River in Tianjin are served as main rivers into the sea. The water quality of the rivers entering the sea is directly related to the water quality of the coastal waters. Although Shanghai is larger than Tianjin in terms of industrial scale and population intensity, however, in 2016, the water quality of Shanghai's rivers into the sea was all at the Class III water quality, while the water quality of Tianjin's rivers entering the sea was all Inferior V level. In 2018, water quality of rivers entering the sea from both of the 2 cities improve better, Shanghai's rivers into the sea was all at the Class II water quality, the ratio of Inferior V level from Tianjin's rivers into the sea dropped to 62.5%.

The results indicated that, the solution of environmental problems has great human factors, the pollution and environmental problems can be solved if urban managers can improve management intensity, increase capital investment, and regard environmental issues as the core issue of sustainable urban development, in this way, the city can promote the coordinated development of the economy and the environment to the greatest extent.

2.3.5 Land polluted sources directly discharged into the sea

(1) Analysis of wastewater directly discharged into the sea

Land-based pollution is one of the most important source of MEP, and wastewater is a major component of land-based pollution. The sources of pollution directly discharged from the land into the sea are usually divided into three types: industrial pollution sources, domestic pollution sources and integrated sewage outlets.

In 2016, 419 industrial pollution sources, sources of life pollution, domestic and comprehensive pollution sources which directly discharged into the sea with a discharge of more than 100 m^3 per day were monitored. In 2016, the total discharge of 419 sources of sewage was about 657.43 million tons. Among the different types of pollution sources, the comprehensive pollution source discharges the largest amount of sewage, followed by the industrial pollution source, and the life pollution source discharges was the least. Among the major pollutants, the comprehensive pollution sources have the largest emissions; the industrial pollution sources have higher hexavalent chromium emissions than life pollution sources, as for other pollutant indicators, industrial pollution sources are lower than life pollution sources.

According to the monitoring of all major pollution sources in 2001-2017, the wastewater discharge kept increasing significantly, as shown in Figure 2-10.

Wastewater from monitored sources directly discharged into to 4 main sea areas of China as shown in Table 2-11, the analysis shows that, the direct discharge of wastewater from the land to the East China Sea is the largest.

(2) Main pollutants from directly discharged into the sea

According to the monitoring data issued by MEE in 2016, among the various types of pollutants, indicators which was above 5% monitored point over-standard are as following: total phosphorus, chemical oxygen demand (COD), ammonia nitrogen, suspended solids, 5-day biochemical oxygen demand (BOD_5) and total nitrogen. The following indicators are had been monitored: the number of fecal coliforms, phosphate (calculated with phosphorus), sulfide, nickel, pH, color, anionic surfactant, benzene, zinc, copper, total organic carbon, toluene and aniline.

The amount of various pollutants monitored had generally declined or remained stable during 2011-2018, as shown in Table 2-12. But there are also some mutation monitoring results in individual years, for example, lead reached 18,087 kg in 2015, the monitoring amount of hexavalent chromium reached 2,919 kg in 2016..

(3) Land pollutants from 3 different kinds of pollution sources

In 2016, the amount of pollutants from 3 different kinds of pollution sources discharged into the sea is much different, as shown in Table 2-13. The pollutants were mainly from comprehensive source, followed by pollutants from life and industry. The pollutants from life is more than that from industry except Hexavalent chromium.

(4) Land pollutants directly discharged into the 4 main sea areas

Among the 4 main sea areas, East China Sea got the largest amount of pollutants; among the major pollutants, COD, petroleum, total nitrogen, total phosphorus, hexavalent chromium, mercury, cadmium, all monitored the largest emissions in East China Sea, and ammonia nitrogen emissions in Yellow Sea was the largest, lead emissions was the largest in Bohai Sea, as shown in Table 2-14.

(5) Land pollutants discharged into sea from 11 coastal provinces of China

Among the 11 coastal provinces in China, Fujian had the largest sewage discharge, followed by Zhejiang and Guangdong; Zhejiang had the largest COD discharge, followed by Liaoning and Fujian, as shown in Table 2-15.

2.3.6 Coastal marine environmental disasters

(1) Red tide

Red tide is one of the main MEP problems in China's offshore waters in recent years. There are many related factors led to the occurrence of red tide, one important factor is that a large amount of nitrogen-containing organic pollutant is discharged into seawater, which makes the eutrophication of seawater more serious, as shown in Table 2-16 and Table 2-17.

(2) Eutrophication

In 2016, the average eutrophication monitored ratio in the coastal waters of China was 31.2%. The eutrophication of moderate level and above moderate level mainly concentrated in Liaodong Bay, Yangtze River estuary, Pearl River Estuary and some coastal waters of Shandong, Jiangsu and Zhejiang.

In the coastal waters of the 4 main sea areas, East China Sea is moderately eutrophic, with eutrophication points monitored ratio of 46.8%; other sea areas have lower eutrophication indexes, the Bohai Sea is 37.0%; the Yellow Sea is 19.8%; and South China Sea is 22.0%.

2.3.7 Marine fishery water environment

(1) Overall Situation

In 2016, the China Fishery Eco-environment Monitoring Network monitored 40 important aquaculture water areas in the Yellow-Bohai Sea, East China Sea, and South China Sea, the total area of monitored water is of 5.958 million hectares.

In 2016, the monitoring area of China's marine natural fishery waters was 5.27 million hectares. In all monitored sea areas, the monitoring concentrations of the following indicators are better than the evaluation standard, for the main pollution indicators of IN, AP, petroleum and COD, ratio of areas superior to evaluation standard were respectively 14.9%, 38.2%, 94.8%, and 76.4%. In 2018, the ratio above evaluation standard had been improved, IN, AP, petroleum and COD, ratio of areas superior to evaluation standard were respectively 24.6%, 56.0%, 95.6%, and 66.1%. There were no heavy metal indicators monitored over evaluation standard. For the indicator of IN, AP and COD in 2016 compared with the year 2015, the ratio of area monitored under the evaluation standard appeared to grow, petroleum indicator reduced.

(2) Environmental conditions of sediments in marine fishery waters

In 2016, China monitored sediments in 29 important marine fisheries. The results showed that, the following indicators monitored results exceed the standard maximum limit, and the ratio of area with over-standard monitored, for petroleum, copper, cadmium and arsenic respectively 8.7%, 3.4%, 3.4% and 3.4%. The average monitoring concentration of zinc, lead and mercury is better than the evaluation standard.

(3) Fishery water pollution accidents

In 2016, according to incomplete statistics, there were 3 incidents of fishery water pollution accidents along the coast of China, resulting in direct economic losses of 1181.6 million CNY. Among the 3 accidents, the typical one is the marine fishery pollution accident in Guangxi in July 2016, a fishery pollution accident occurred in the shallow sea culture area of Qinzhou, Guangxi Zhuang Autonomous Region, causing a large number of marine life deaths, with a pollution area of 1333.3 hectares and economic losses of 1,000 CNY.

2.4 Main countermeasures to prevent MEP

2.4.1 Economic development and its effect to MEP

Although China's coastal MEP had improved in recent years, but still not optimistic. In the provinces and cities in China's coastal areas, due to the serious pollution of land-based sources, MEP in these areas is also relatively serious. Therefore, it is necessary to explore and implement the total control of marine environmental pollutants, and coordinate the realization of economic and environment. Relying on the location, capital, talents and technological advantages of coastal areas, optimization and upgrading of industrial structure in coastal areas are encouraged.

A circular economy can contribute to improve marine environment, this need to strengthen the management of key industrial pollution sources, reduce the amount of industrial waste generated, prohibited the discharge of toxic and hazardous substances from industrial pollution sources. Moreover, it needs to completely eliminate untreated industrial wastewater directly discharged into the sea. Implement pollutants discharge permit system, and implement the total pollutant discharge reduction number for each enterprise with directly pollution source discharge to sea, this will lead the total pollutant discharge amount has a planned stable reduction.

2.4.2 Main threats to MEP and countermeasures

Strengthening marine environmental monitoring, reducing and eliminating the following factors may bring danger challenges to marine environmental pollution

(1) Industrial pollutants to the sea in coastal cities

China's coastal cities had developed rapidly and the MEP pressure on coastal waters of these citied kept intensified. Facing this challenge, it need to accelerate the construction of sewage collection pipe networks and domestic sewage treatment facilities in coastal towns, increase the capacity of urban sewage collection and treatment, and improve the capacity of denitrification and dephosphorization of urban sewage treatment facilities.

(2) Reduce agricultural pollutants

Comprehensively set up the technical system of reducing fertilizer and pesticide runoff, and reduce the agricultural non-point source pollution load. Strictly control the density and scale of livestock and poultry farming in the terrestrial catchment area of environmentally sensitive sea areas.

(3) Reduce coastal marine pollutants

Implement the “Zero Emissions” plan for marine oil pollutants, implement the sealing system for ship sewage equipment, and strengthen the pollution prevention and control of fishing ports and fishing boats. Establish more large port with recovery and treatment system for wastewater, waste oil and waste residue. Monitor the discharge to sea, implement centralized transportation of pollutants discharged from transportation and fishing vessels, pollutants need to be onshore purified treatment as much as possible. Formulate contingency plans for oil spills and toxic chemical spills at sea, formulate emergency plans for port MEP accidents, and establish emergency response systems to prevent and reduce sudden pollution accidents.

China's marine aquaculture is mainly located in shallow beaches and inner bay waters with poor water exchange capacity. The cultivation of self-polluting caused local water environment deterioration. In the future, the environmental management system and standards for marine aquaculture areas should be established, the density and area of sea culture should be controlled reasonably, drug in the aquaculture industry should be controlled.

Oil and other pollutants from offshore oil platforms and domestic garbage pollution will cause MEP problems. In the offshore because of oil drilling aims to oil production, brought various problems that damage to marine ecological system. So, the oil platforms should be equipped with oil sewage, domestic sewage treatment facilities, so that all of them meet the standard for discharging. Coastal oil exploration and development should set up emergency response mechanism for oil spilling accident.

(4) Garbage dumped to the ocean

Strictly manage and control the dumping of waste garbage into the ocean, especially prohibit the dumping of radioactive waste and hazardous materials into the sea.

2.4.3 Increase the ability of marine environmental protection

The comparative analysis of marine environmental pollution in different China coastal regions showed that, improving marine environmental awareness and adopting comprehensive measures to control land-based pollution and discharge into seas can effectively improve marine environmental pollution. By strengthening the enforcement of marine environment management and increasing investment in marine environmental protection funds, the process of MEP can be mitigated to the greatest extent. For the sea areas with serious MEP in Yellow Sea, Bohai Sea and the East China Sea, stricter environmental protection policies should be adopted. Adhere to the principle of adapting to local conditions to deal with the specific problems of the marine environment, for example, in the Bohai Rim region, due to special natural conditions, the marine environment capacity of the area is extremely limited, therefore, the plan for marine environmental management should be scientifically formulated according to actual conditions.

2.5 Summary

China has vast sea areas and coastal areas, with the population and economy of the coastal provinces of China. According to the standards for evaluating the quality of surface water and seawater in China, the overall situation of China's latest MEP marine environmental pollution is still very serious. The main pollution indexes of seawater quality, including inorganic nitrogen, active phosphate, chemical oxygen demand (COD) and petroleum pollution changed better these years, but the monitored ratio below the standard is still relatively high. The effects of MEP disasters such as red tide and green tide were the result of MEP accumulation. MEP mainly comes from the flowing rivers and land sewage outlets into the sea not meeting the standards, this means that the land pollution source control is very important to MEP. MEP of four main sea areas in China (the Bohai Sea, Yellow Sea, East China Sea and South China Sea), 11 coastal provinces and many coastal cities have much different characteristics, show the co-relation between economy and MEP.

Table 2-1 GDP of China, the U.S, and Japan in the World in 2000 and 2017

	2000		2017	
	GDP (trillion US $)	Proportion (%)	GDP (trillion US $)	Proportion (%)
World	33.28	100.00	81.00	100.00
China	1.22	3.65	12.25	15.10
Japan	4.89	14.70	4.88	6.03
United States	10.28	30.90	19.36	23.90

Data source: World Economic Network, 2018

Table 2-2 Structure of China marine industry in 2016 and 2017

Marine industry	2016 Production (billion CNY)	2016 Proportion (%)	2017 Production (billion CNY)	2017 Proportion (%)
Coastal tourism	1256.3	42.9	1463.6	46.1
Transportation	576.4	19.7	631.2	19.9
Fishing	483.6	16.5	467.6	14.7
Construction industry	182.5	6.2	184.1	5.8
Shipbuilding industry	152.2	5.2	145.5	4.6
Oil & gas industry	115.0	3.9	112.6	3.5
Chemical industry	105.2	3.6	104.4	3.3
Biology medicine industry	34.7	1.2	38.5	1.2
Power industry	12.7	0.4	13.8	0.4
Mining industry	7.0	0.2	6.6	0.2
Salt industry	4.6	0.2	4	0.1
Sea water utilization	1.4	0.0	1.4	0.0

Source: State Oceanic Administration (SOA) of China, China Marine Economic Statistics Bulletin, 2016 and 2017.

Table 2-3 Classes of sea water quality in China coastal areas (2001-2018) (%)

	Class I	Class II	Class III	Class IV	Inferior Class IV	Class I + Class II	Total
2001	13.4	28.0	12.2	11.9	34.5	41.4	100.0
2002	21.3	28.4	14.4	8.9	27.0	39.7	100.0
2003	19.8	30.4	19.8	8.5	21.5	50.2	100.0
2004	11.4	38.2	15.4	11.8	23.2	49.6	100.0
2005	32.0	35.2	8.9	5.5	18.4	67.2	100.0
2006	28.8	38.9	8.0	7.3	17.0	67.7	100.0
2007	26.0	36.8	11.8	7.1	18.3	62.6	100.0
2008	31.9	38.5	11.3	6.3	12.0	70.4	100.0
2009	30.1	42.8	6.0	6.7	14.4	72.9	100.0
2010	31.5	31.2	14.1	4.7	18.5	62.7	100.0
2011	25.2	37.6	12.0	8.3	16.9	62.8	100.0
2012	29.6	39.5	6.7	5.3	18.6	69.1	100.0
2013	24.6	41.8	8.0	6.7	18.6	66.4	100.0
2014	28.6	38.2	7.0	7.6	18.6	66.8	100.0
2015	33.6	36.9	7.6	3.7	18.3	70.5	100.0
2016	32.4	41.0	10.3	3.1	13.2	73.4	100.0
2017	34.5	33.3	10.1	6.5	15.6	67.8	100.0
2018	46.1	28.5	6.7	3.1	15.6	74.6	100.0

Data Source: Ministry of Environmental and Ecology (MEE) of China, 2001-2018. China Coastal Marine Environment Bulletin (CCMEB).

Table 2-4 Sea water quality along 11 coastal provinces sea areas in 2016 and 2017 (%)

Province	Year	Class I	Class II	Class III	Class IV	Inferior Class IV
Liaoning	2016	35.0	48.3	6.7	6.7	3.3
	2017	41.7	48.3	3.3	1.7	5.0
Hebei	2016	23.1	53.8	0.0	7.7	15.4
	2017	0	76.9	0	7.7	15.4
Tianjin	2016	0.0	33.3	66.7	0.0	0.0
	2017	8.3	16.7	50.0	25.0	0.0
Shandong	2016	46.2	47.7	4.6	1.5	0.0
	2017	32.3	49.2	7.7	6.2	4.6
Jiangsu	2016	18.2	50.0	13.6	13.6	4.5
	2017	13.6	31.8	36.4	9.1	9.1
Shanghai	2016	0.0	0.0	30.0	0.0	70
	2017	0	10.0	20.0	0.0	70.0
Zhejiang	2016	8.9	19.6	12.5	5.4	53.6
	2017	10.7	12.5	17.9	14.3	44.6
Fujian	2016	19.1	53.2	14.9	2.1	10.6
	2017	25.5	57.4	4.3	6.4	6.4
Guangdong	2016	16.9	62.0	11.3	0.0	9.9
	2017	46.5	11.3	9.9	5.6	26.8
Guangxi	2016	91.3	4.3	0.0	0.0	4.3
	2017	73.9	17.4	0.0	4.3	4.3
Hainan	2016	78.9	21.1	0.0	0.0	0.0
	2017	68.4	31.6	0.0	0.0	0.0

Source: MEE of China, 2016 and 2017. CCMEB.

Table 2-5

Percentage of inferior class IV sea water quality along 11 coastal provinces (2011-2017) (%)

Province	2011	2012	2013	2014	2015	2016	2017
Shanghai	60.0	80.0	70.0	80.0	70.0	70.0	70.0
Zhejiang	56.0	68.0	76.0	70.0	70.0	53.6	44.6
Guangdong	15.4	11.5	11.5	11.5	11.5	9.9	26.8
Hebei	0	0	0	0	0	15.4	15.4
Jiangsu	0	0	0	6.2	12.5	4.5	9.1
Fujian	11.4	5.7	5.7	5.7	5.7	10.6	6.4
Liaoning	17.9	0	0	0	0	3.3	5.0
Shandong	0	0	0	0	0	0	4.6
Guangxi	0	0	0	4.5	0	4.3	4.3
Tianjin	40.0	60.0	30.0	30.0	30.0	0	0
Hainan	0	0	0	0	0	0	0

Source: MEE of China, 2011-2017. CCMEB.

Table 2-6

Over-standard pollutants monitored ratio in China's coastal waters (2001–2017) (%)

Year	inorganic nitrogen	active phosphate	COD	petroleum	lead	copper	mercury	cadmium
2001	67.9	59.9	1.9	18.0	62.9	25.9	6.6	2.0
2002	49.0	49.2	16.1	12.9	48.6	22.2	7.9	2.5
2003	37.5	23.6	4.2	16.0	3.4	5.1	0.8	0.0
2004	34.8	23.5	2.4	9.9	6.4	8.0	3.4	0.0
2005	30.5	20.3	1.8	4.9	2.5	0.7	0.0	0.1
2006	31.4	14.4	2.9	2.9	2.2	0.8	0.2	0.1
2007	34.1	13.4	2.1	3.0	4.0	1.4	0.0	0.0
2008	27.5	10.4	1.1	1.0	1.8	0.7	0.0	0.2
2009	28.3	14.7	1.0	1.5	2.0	0.8	0.3	0.4
2010	35.0	15.0	1.3	2.9	1.2	0.4	0.5	0.5
2011	29.6	11.0	1.7	4.3	5.3	1.3	-	1.0
2012	28.6	15.9	0.3	2.3	0.3	-	-	
2013	28.6	15.6	4.3	2.0	1.0	-	-	0.3
2014	31.2	14.6	1.0	1.7	-	-	-	-
2015	29.2	14.6	1.0	-	0.3	-	-	-
2016	23.3	10.1	0.7	2.2	0.5	0.5	-	-
2017	30.2	7.0	0.7	1.4	-	0.7	-	-

Note: The data in the table is the number of monitored over-punctuation points as the % of the total number of monitoring points; - means had no valid data monitored

Source: MEE of China, 2011-2017. CCMEB.

Table 2-7 Over-standard pollutants in China's 4 main sea areas in 2016 and 2017 (%)

Area	Year	inorganic nitrogen	active phosphate	COD	fecal coliform	pH
National average	2016	23.3	10.1	-	-	-
	2017	30.2	7.0	0.5	-	-
Bohai	2016	19.8	-	-	-	-
	2017	28.4	-	-	-	-
Yellow Sea	2016	9.9	-	-	-	-
	2017	15.4	-	-	-	-
East China Sea	2016	55.8	27.4	2.7	0.9	-
	2017	53.1	15.9	-	-	-
South China Sea	2016	6.8	5.3	-	-	7.6
	2017	22.0	6.8	-	-	6.8

Note: The data in the table is the percentage of over-standard points of all monitoring points.

- mean no value monitored

Source: MEE of China, 2016 and 2017. CCMEB.

Table 2-8 Water quality to the sections of monitored rivers into the sea (2011-2018) (%)

Year	Class Ⅰ (1)	Class Ⅱ (2)	Class Ⅲ (3)	Class Ⅳ (4)	Class Ⅴ (5)	Inferior Class V (6)	Total	Class Ⅰ-III (1)+(2)+(3)
2011	0.5	11.9	32.5	20.1	7.7	27.3	100.0	44.9
2012	0.0	13.4	33.3	20.9	8.0	24.4	100.0	46.7
2013	0.0	12.5	34.0	24.0	11.0	18.5	100.0	46.5
2014	0.0	15.1	27.3	26.3	13.1	18.2	100.0	42.6
2015	0.0	11.3	30.2	22.6	14.1	21.5	100.0	41.5
2016	0.0	13.5	33.3	25.5	10.4	17.2	100.0	46.8
2017	0.0	13.8	33.8	24.6	6.7	21.0	100.0	47.6
2018	0.0	20.6	25.3	26.8	12.4	14.9	100.0	45.9

Source: MEE of China, 2011-2018. CCMEB.

Table 2-9

Water quality to the sections of rivers into the 4 China's main sea areas (2016-2018) (%)

Area	Year	Class Ⅰ	Class Ⅱ	Class Ⅲ	Class Ⅳ	Class Ⅴ	Inferior Class V
Bohai Sea	2016	0.0	4.3	8.7	34.8	17.4	34.8
	2017	0.0	2.1	10.6	23.4	14.9	44.6
	2018	0.0	8.7	8.7	30.4	30.4	21.7
Yellow Sea	2016	0.0	5.9	31.4	31.4	15.7	15.7
	2017	0.0	0.2	35.8	35.8	9.4	17.0
	2018	0.0	9.4	20.8	37.7	13.2	18.7
East China Sea	2016	0.0	12.0	56.0	24.0	8.0	0.0
	2017	0.0	0.1	68.0	16.0	0.04	0.04
	2018	0.0	32.0	40.0	24.0	4.0	0.0
South China Sea	2016	0.0	25.7	42.9	15.7	2.9	12.9
	2017	0.0	30.0	35.7	20.0	0	14.3
	2018	0.0	32.9	34.3	17.1	2.9	12.9

Note: The data in the table is the over-standard points that detected ratio in %.

Source: MEE of China, 2016-2018. CCMEB.

Table 2-10

Water quality of rivers into the seas along 11 coastal provinces of China (2016-2018) (%)

Province	year	Class Ⅰ	Class Ⅱ	Class Ⅲ	Class Ⅳ	Class Ⅴ	Inferior Class Ⅴ
Liaoning	2016	0.0	10.5	15.8	52.6	10.5	10.5
	2017	0.0	15.8	21.1	26.3	15.8	21.1
	2018	0.0	16.7	22.2	38.9	11.1	11.1
Hebei	2016	0.0	8.3	16.7	33.3	0.0	41.7
	2017	0.0	8.3	25.0	25.0	0.0	41.7
	2018	0.0	16.7	16.7	16.7	41.7	8.3
Tianjin	2016	0.0	0.0	0.0	0.0	0.0	100.0
	2017	0.0	0.0	0.0	0.0	0.0	100.0
	2018	0.0	0.0	0.0	12.5	25.0	62.5
Shanghai	2016	0.0	0.0	100.0	0.0	0.0	0.0
	2017	0.0	0.0	100.0	0.0	0.0	0.0
	2018	0.0	100.0	0	0.0	0.0	0.0
Jiangsu	2016	0.0	0.0	38.7	35.5	12.9	12.9
	2017	0.0	0.0	41.9	32.3	3.2	22.6
	2018	0.0	3.2	25.8	32.3	12.9	22.6
Zhejiang	2016	0.0	7.7	53.8	30.8	7.7	25.8
	2017	0.0	7.7	61.5	23.1	7.7	0.0
	2018	0.0	38.5	23.1	38.5	0.0	0.0
Fujian	2016	0.0	18.2	54.5	18.2	0.1	0.0
	2017	0.0	9.1	72.7	9.1	0.0	9.1
	2018	0.0	18.2	63.6	9.1	9.1	0.0
Guangdong	2016	0.0	30.0	30.0	17.5	2.5	20.0
	2017	0.0	27.5	32.5	17.5	0.0	22.5
	2018	0.0	30.0	32.5	15.0	0.0	22.5
Guangxi	2016	0.0	0.0	72.7	18.2	0.0	9.1
	2017	0.0	0.0	54.5	36.4	0.0	9.1
	2018	0.0	9.1	54.5	27.3	9.1	0.0
Hainan	2016	0.0	31.6	52.6	10.5	5.3	0.0
	2017	0.0	0.0	54.5	36.4	0.0	9.1
	2018	0.0	52.6	26.3	15.8	5.3	0.0

Source: MEE of China, 2016-2018. CCMEB.

Table 2-11 Wastewater from sources directly discharged into the seas of China (2011-2018)

Year	Bohai Sea (billion ton)	Yellow Sea (billion ton)	East China Sea (billion ton)	South China Sea (billion ton)	Total (billion ton)
2011	1.66	9.09	27.02	9.58	47.40
2012	1.81	10.51	34.03	9.64	55.99
2013	2.06	11.04	37.45	12.29	63.84
2014	2.99	10.58	38.37	11.17	63.11
2015	2.19	10.47	39.61	10.18	62.45
2016	2.37	11.92	40.90	10.55	65.74
2017	2.36	11.26	38.80	11.18	63.60
2018	6.87	11.72	55.68	12.37	86.64

Note: * each of the monitored sources of pollution directly discharged into the sea, its amount of polluted water discharged into the ocean is more than 1 million m^3 per day

Source: MEE of China, 2011-2018. CCMEB.

Table 2-12 Pollutants of directly discharged sources into the sea (2011-2018)

	COD (10^4t)	Ammonia nitrogen (10^4t)	Petro (t)	Total nitrogen (t)	Total phosphorus (t)	Hexavalent chromium (kg)	Lead (kg)	Hg (kg)	Cadmium (kg)
2011	21.0	2.02	907	-	3047	451	3017	322	879
2012	21.8	1.71	1026	-	2921	2753	4587	228	826
2013	22.1	1.69	1636	-	2841	1908	7681	213	392
2014	21.1	1.48	1199	-	3126	1611	5801	281	864
2015	21.0	1.54	824	-	3149	1089	18087	190	623
2016	19.9	1.53	788	64466	2739	2919	4665	218	460
2017	17.2	1.08	906	56625	2169	2335	3858	243	543
2018	14.76	6.21	457.6	50873	1280	3972	8238	277	407

Note: each of the monitored sources of pollution directly discharged into the sea, its amount of polluted water discharged into the ocean is more than 1 million m^3 per day

-means no results monitored

Source: MEE of China, 2011-2018. CCMEB.

Table 2-13 Pollutants discharged from 3 kinds pollutions sources into the sea in 2016-2018

		COD (10^4t)	Petro (t)	Ammonia nitrogen (t)	Total nitrogen (t)	Total phosphorus (t)	Hexavalent chromium (kg)	Lead (kg)	Hg (kg)	Cadmium (kg)
Industry	2016	2.89	104	946	3040	106	230	589	2.4	34
	2017	2.11	153	711	3594	120	361	470	1.8	9.0
	2018	3.21	93	915	5984	124	435	2095	19.2	18.0
Life	2016	3.53	157	5274	11714	586	191	1098	27.4	52
	2017	2.41	290	1946	7058	385	130	423	5.9	18.1
	2018	1.53	70	921	6657	207	483	1382	42.5	128.4
Compre-hensive	2016	13.33	528	9084	49712	2047	2498	2977	188.6	374
	2017	12.72	463	8102	45973	1664	1844	2965	235.7	516.3
	2018	10.02	295	4381	38232	949	3054	4760	215.3	260.1
Total	2016	19.86	788	15304	64466	2739	2919	4665	218.4	460
	2017	17.24	906	10759	56625	2169	2335	3858	243.4	543.4
	2018	14.76	458	6217	50873	1280	3972	8238	277.0	406.9

Source: MEE of China, 2016-2018. CCMEB.

Table 2-14 Pollutants discharged directly to 4 sea areas of China in 2016-2018

	COD (10^4t)	Ammonia nitrogen (t)	Petro (t)	Total nitrogen (t)	Total phosphorus (t)	Hexavalent chromium (kg)	Lead (kg)	Hg (kg)	Cadmium (kg)
Bohai									
2016	1.35	2877	10.7	5371	317	544.5	1155.4	9.2	30.4
2017	0.70	2548	12.7	3717	190	242.6	388.0	12.1	5.27
2018	0.72	464	12.9	3717	59	297.1	215.8	28.4	68.1
Yellow									
2016	5.99	6563	122.9	16938	652	215.6	242.3	52.8	41.4
2017	3.85	2524	314.7	9928	467	244.5	158.2	98.7	95.6
2018	3.30	1313	116.4	9961	252	2007.3	3325.4	133.1	90.1
East									
2016	10.09	4121	435.3	33444	1003	2121.2	753.5	123.9	344
2017	9.98	3843	430.8	31975	884	1757.3	1400.9	106.7	320.3
2018	7.98	2282	282.7	26533	458	1283.8	1120.5	62.9	116.2
South									
2016	2.44	1743	219.3	8713	767	38.2	2513.4	32.5	44.2
2017	2.71	1844	148.1	10395	627	90.4	1910.6	25.9	122.2
2018	2.76	2158	45.7	10662	511	383.3	3576.2	52.5	132.5

Source: MEE of China, 2016-2018. CCMEB.

Table 2-15 Pollutants directly discharged into the seas along11 coastal provinces in 2016 and 2018

		COD (10^4t)	Petro (t)	Ammonia nitrogen (10^4t)	Total nitrogen (t)	Total phosphorus (t)	Hexavalent chromium (kg)	Lead (kg)	Hg (kg)	Cadmium (kg)
Liaoning	2016	3.42	89.4	6406	11620	425	534.6	562.2	31.5	-
	2018	1.22	43	493	3023	98	233.2	3.03	4.7	-
Hebei	2016	0.15	-	730	1341	108	-	6.6	-	0.5
	2018	0.24	-	231	2191	24	87.2	38.6	20.5	-
Tianjin	2016	0.85	3.9	682	1128	173	-	23.8	5.7	29.9
	2018	0.06	1.1	41	208	5	33.2	29.0	0.01	0.05
Shandong	2016	2.67	30.1	1510	7709	225	193.5	805.0	20.1	19.5
	2018	2.33	75.9	938	7777	170	1945.1	3378	132.9	157.6
Jiangsu	2016	0.22	10.2	111	511	38	31.9	-	4.8	21.8
	2018	0.18	9.2	74	479	15	5.7	92.8	3.4	0.56
Shanghai	2016	0.57	48.5	404	2503	155	-	406.7	36.6	109
	2018	0.47	23.5	235	2120	34	143.6	254.3	17.0	35.1
Zhejiang	2016	7.03	316.5	2924	25562	612	2080	170.1	61.4	210.7
	2018	5.62	189	1445	19307	301	910.4	750.7	16.9	63.3
Fujian	2016	2.49	70.3	793	5379	235	41.4	176.8	26.0	24.3
	2018	1.89	70	602	5106	123	229.9	115.5	29.0	17.8
Guangdong	2016	1.22	92.1	874	4551	333	0.2	1110.7	24.5	2.2
	2018	1.61	22	1507	6849	293	383.6	2723	46.1	115.1
Guangxi	2016	0.43	23.9	349	1416	343	40	555.1	7.9	42
	2018	0.29	12.4	125	1337	136	-	678.3	4.4	4.39
Hainan	2016	0.78	103.3	521	2746	92	-	847.6	0.03	-
	2018	0.86	11.1	526	2476	83	0.22	175.3	2.02	13.0

Source: MEE of China, 2016 and 2018. CCMEB.

Table 2-16 Red tide frequencies in China's coastal waters, 2001-2018

Year	Bohai Sea	Yellow Sea	East China Sea	South China Sea	Total
2001	20	8	34	15	77
2002	3	14	51	11	79
2003	5	12	86	16	119
2004	12	13	53	18	96
2005	9	13	51	9	82
2006	11	2	63	17	93
2007	7	5	60	10	82
2008	1	12	47	8	68
2009	4	13	43	8	68
2010	7	9	39	14	69
2011	13	8	23	11	55
2013	13	2	25	6	46
2015	7	1	15	12	35
2017	12	3	40	13	68
2018	5	1	23	7	36

Note: data of year 2012, 2014 and 2016 had not been got

Source: State Oceanic Administration (SOA) of China, 2001-2018, Bulletin of China Marine Ecological Environmental Status (BCMEES).

Table 2-17 Cumulative areas of red tide in 4 sea areas of China in 2011-2018 (km^2)

Area	2011	2013	2015	2017	2018
Bohai Sea	217	1880	1522	342	62
Yellow Sea	4242	450	48	100	35
East China Sea	1427	1573	1098	2189	1107
South China Sea	190	167	141	1048	1406
Total	6076	4070	2809	3679	2610

Data Source: China's coastal water quality environmental bulletin 2011-2018

Source: SOA of China, 2011-2018, BCMEES

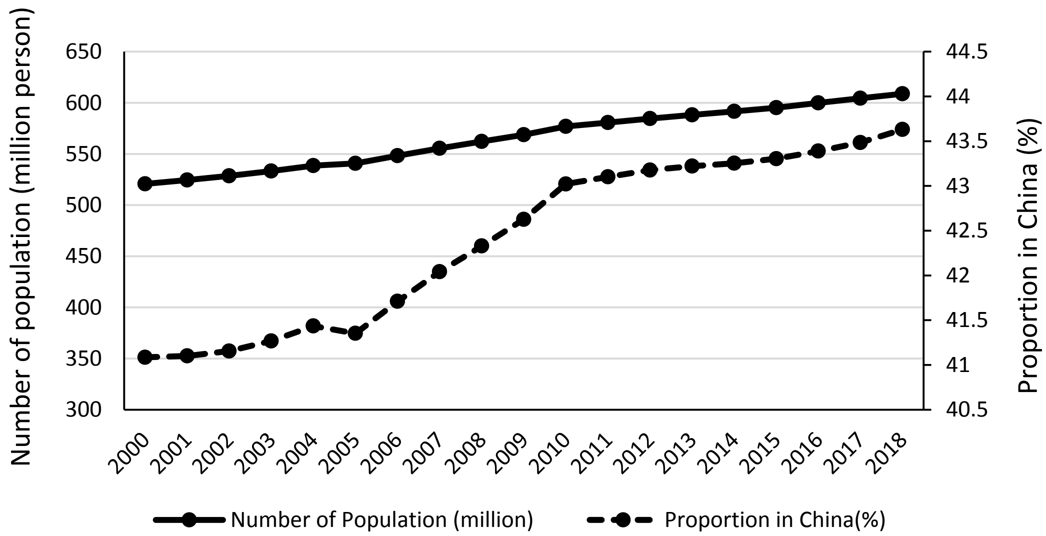

Figure 2-1 Population of all 11 coastal provinces and their proportion in China, 2000-2018

Data Sources: National Bureau of Statistics (NBS) of China. 2000-2018. China Statistical Yearbook (CSY).

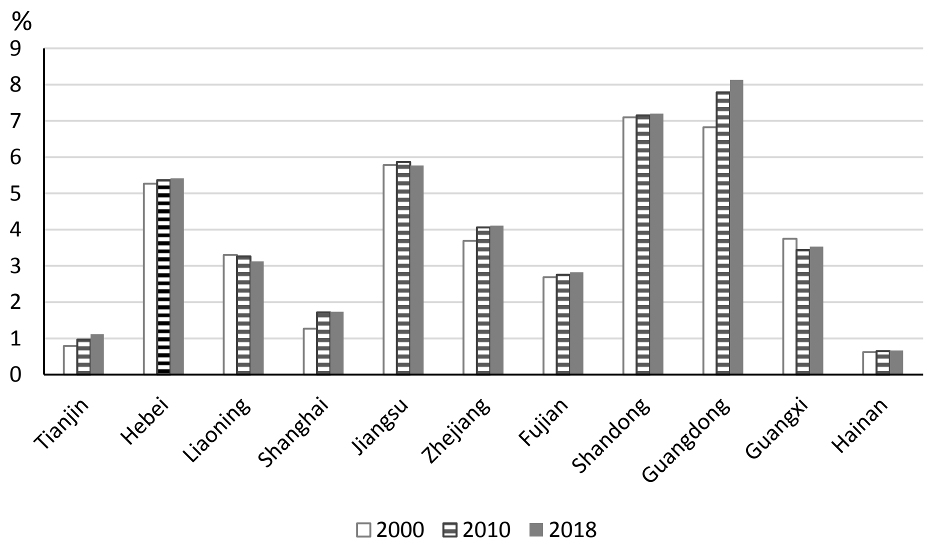

Figure 2-2 Proportion of population in 11 coastal provinces, 2000, 2010 and 2018

Data Sources: NBS of China. 2000, 2010 and 2018. CSY.

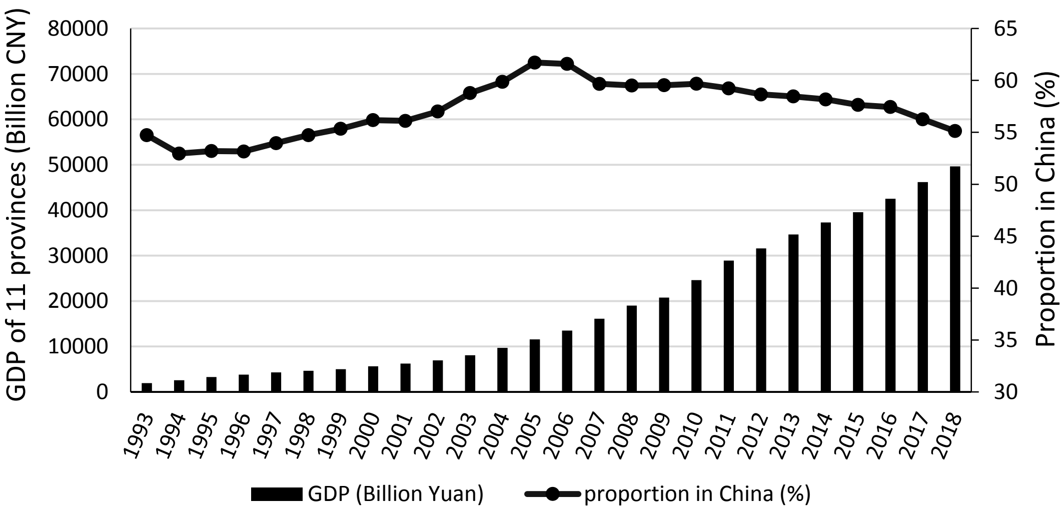

Figure 2-3 GDP of 11 coastal provinces and their proportion in China, 1993-2018

Data source: NBS of China. 1993-2018. CSY.

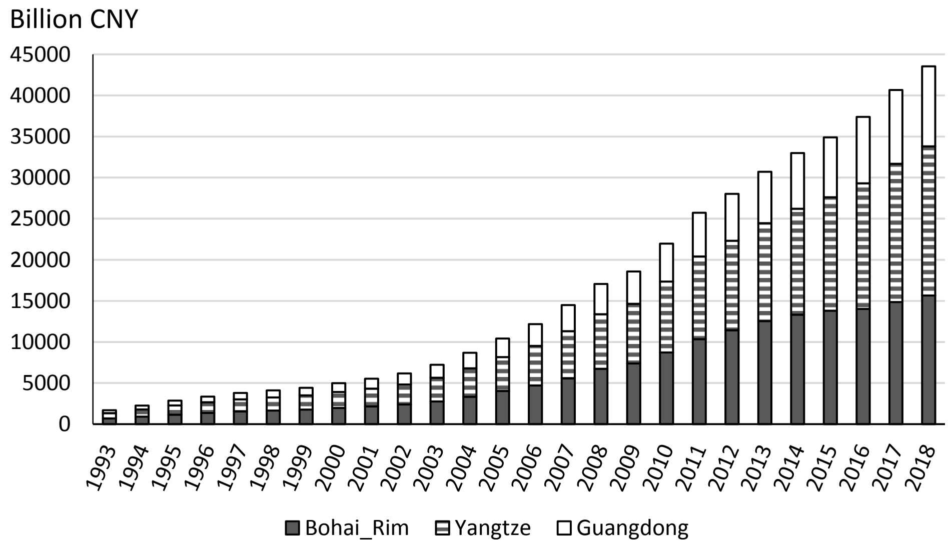

Figure 2-4 GDP of Bohai Rim, Yangtze Delta and Guangdong, 1993-2018

Data source: NBS of China. 1993-2018. CSY.

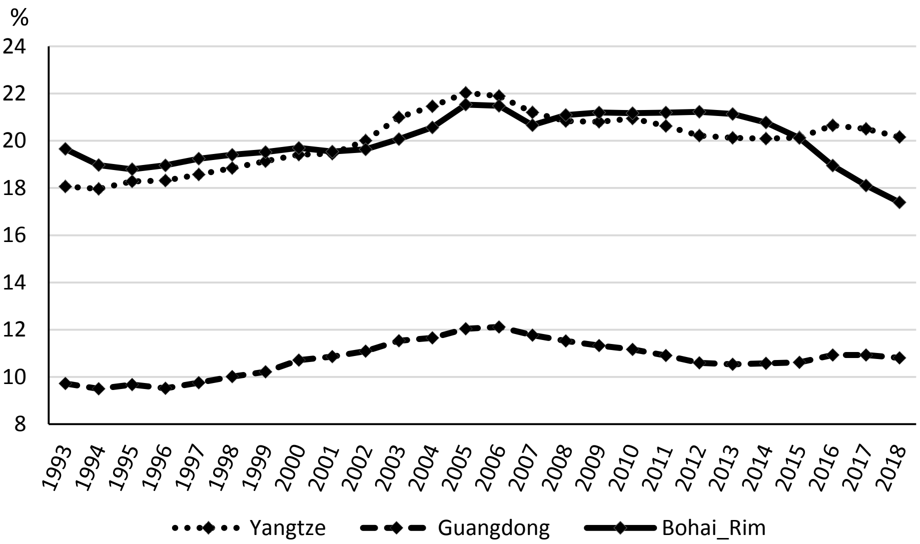

Figure 2-5 Ratio of GDP in China for Bohai Rim, Yangtze Delta and Guangdong, 1993-2018

Data source: NBS of China. 1993-2018. CSY.

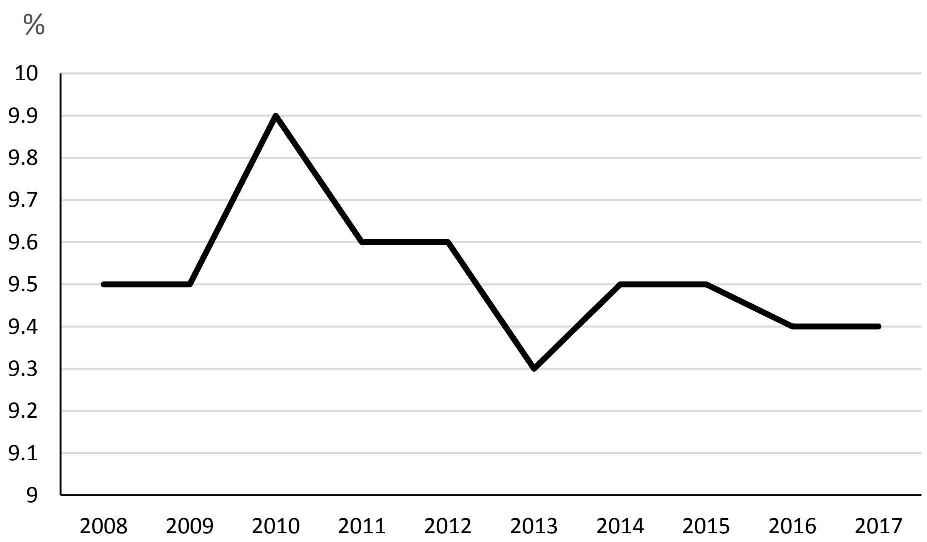

Figure 2-6 Marine industry in China's GDP (2008-2017)

Data Source: SOA of China, 2008-2017, China Marine Economic Statistics Bulletin (CMESB).

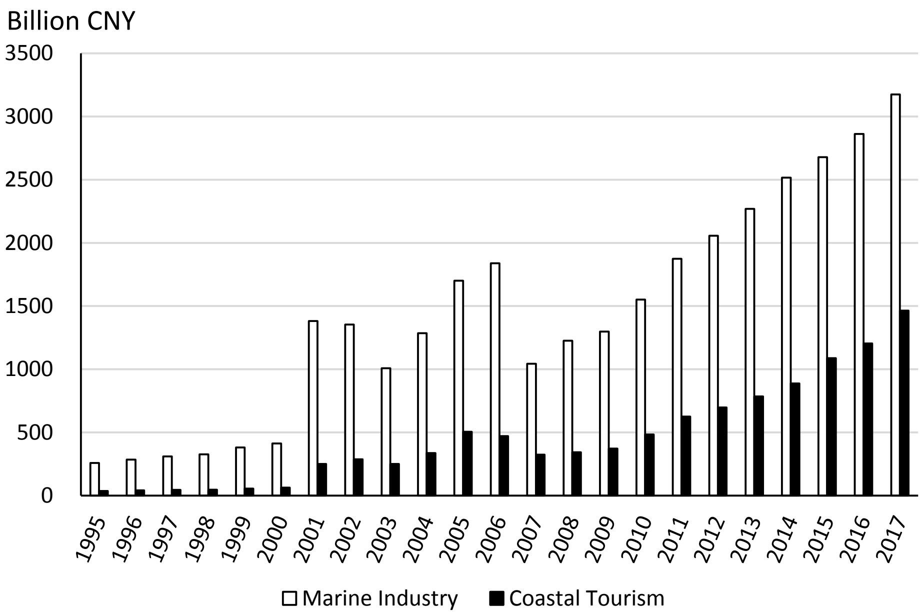

Figure 2-7 Coastal tourism and marine industry in China, 1995-2017

Data Source: SOA of China, 1995-2017, CMESB.

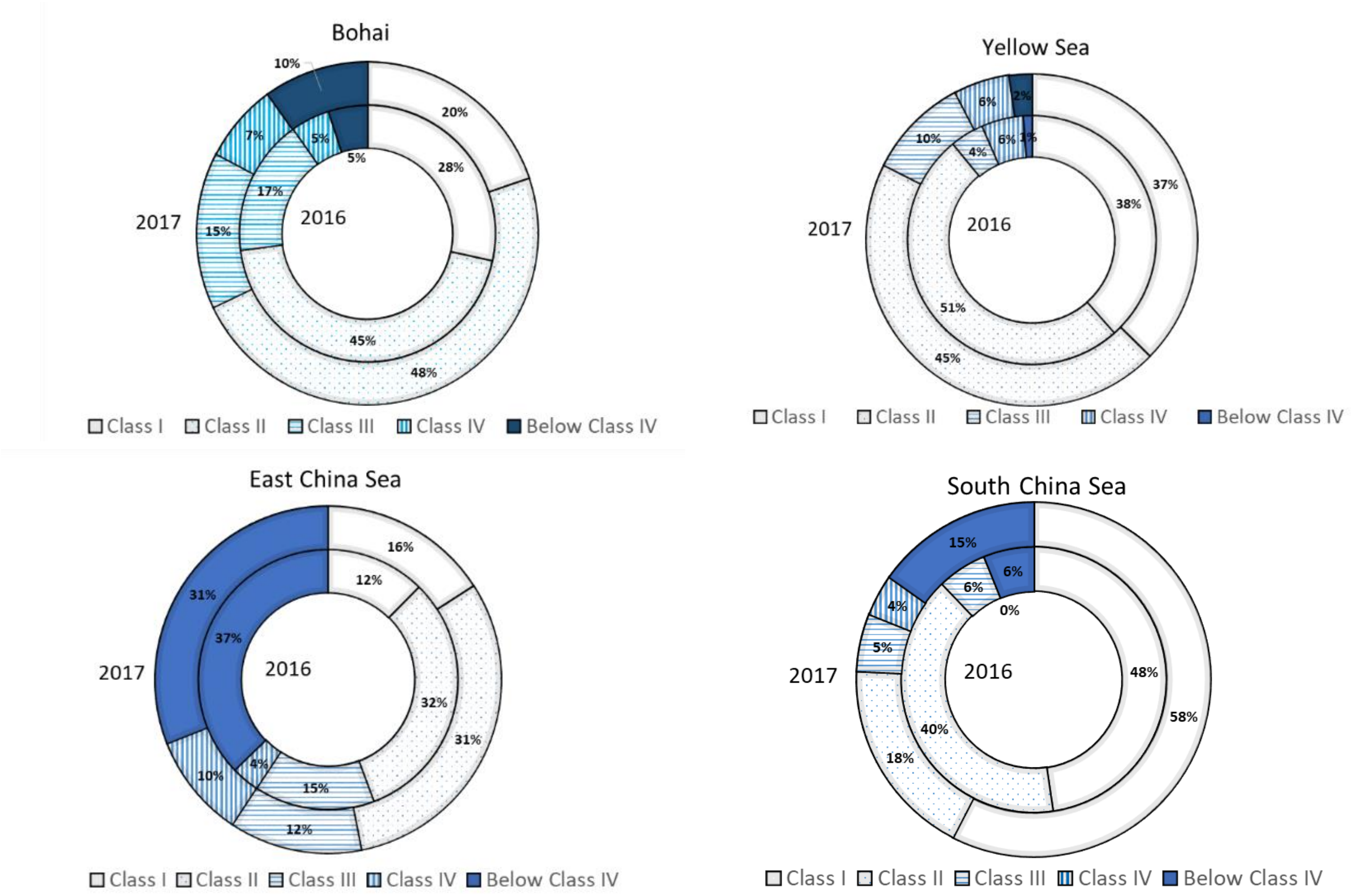

Figure 2-8 Seawater quality in China coastal waters of four sea areas, 2016 and 2017

Source: MEE of China, 2016 and 2017. CCMEB

Note: Class I adapted to marine fisheries waters, marine nature reserves and cherish endangered marine life reserves; Class II adapted to aquaculture areas, bathing beaches, marine sports or recreational areas where human body is in direct contact with sea water, industrial water areas directly related to human consumption; Class III adapted to general industrial water area, coastal scenic tourist area; Class IV adapted to marine port waters, marine development operations.

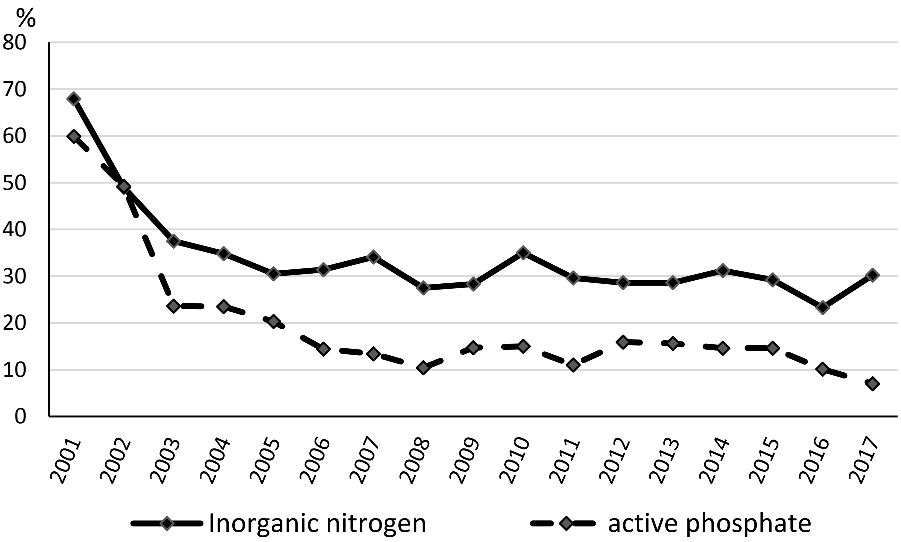

Figure 2-9 Main pollutants over-standard detected in China coastal waters, 2001-2017

Source: MEE of China, 2001- 2017. CCMEB.

Figure 2-10 Wastewater from sources directly discharged into the sea of China, 2001-2017

Source: MEE of China, 2001- 2017. CCMEB.

Chapter 3 Case Study on Shandong Province

3.1 Introduction

3.1.1 Objective

China's coastal areas are a vast region, and the study of MEP all over China is really a complex issue involving many factors. In order to study the MEP problem of China in a more in-depth and specific level, selecting a coastal area as a case study it is an effective method. So, this study selected China's coastal peninsula Shandong Province as a case, studied the general issues of MEP, the relationship between the MEP and economic development, especially the relationship between the MEP and the land-based pollution, the relationship between MEP and regional energy and economic structure, as well as the coastal tourism industry in the marine industry, and its relation with MEP, etc. Through this case study to get further knowledge and analysis on some more specific issues related to China's MEP.

3.1.2 Why select Shandong Province as a case study

(1) Background of Shandong Peninsula

Shandong peninsula is China's largest peninsula, it borders the Bohai Sea and the Yellow Sea, also facing the Korean peninsula and the Japanese islands across the sea. It is also the estuary of the Yellow River, which is the 2nd longest river in China. Its location is in the middle two important economic regions in China, Yangtze River Delta in the south, and Beijing-Tianjin-Hebei metropolitan area in the north.

Analysis of Shandong's industrial structure, the second industry[2] had been a proportion of more than 50% for a long time, which brought great pressure on environmental protection. In recent years, the tertiary industry begun to surpass the secondary industry, providing favorable conditions for environmental improvement, as showed in Figure 3-1.

(2) Marine resources of Shandong have unique advantages

The coastline of Shandong Peninsula has a total length of 3345 km, accounting for 1/6 of the coastline of China's mainland. There are more than 200 bays along the coast, most of them are semi-enclosed. There are 320 islands with the area over 500m^2 around the peninsula, and

[2] Three types industries-According to the definition of the National Bureau of Statistics of China: The division of the three types industries is a more common classification of industrial structures in the world, but the division of countries is not consistent. The three types industrial divisions in China are:
The primary industry refers to agriculture, forestry, animal husbandry and fishery.
The secondary industry refers to the mining, manufacturing, electricity, gas and water production and supply industries, and the construction industry.
The tertiary industry refers to other industries except the primary and secondary industries.

most of these islands are undeveloped. Shandong is a famous important coastal tourist attraction in northern China.

The coastal ports in Shandong Province have 184 deep-water berths with a total throughput of 730 million tons, accounting for 15% of the total throughput of China's coastal ports.

(3) Shandong Peninsula Blue Economy Zone

Blue Economy means marine economy in China. “Shandong Peninsula Blue Economy Zone Development Planning” was issued by China State Council in 2011 (CSC, 2011), it is the first regional development strategy targeting on marine economy in China. The main objectives of implementing this plan are to vigorously develop the marine economy, scientifically develop marine resources, and cultivate marine superior industries.

From the perspective of the spatial structure of the eastern coast of China, Shandong is an important combination zone of Bohai Sea region and Yangtze River Delta. At the same time, Shandong is also in the position of combining the Yellow Sea and the Bohai Sea, so, Shandong has an important strategic position in the economic development of China's coastal areas, leading the development of China's marine industry and marine ecological environment protection, so, select Shandong Province as a coastal area for further research has typical meaning in China.

(4) Marine ecological environment system

Shandong is a typical warm temperate monsoon climate with low typhoon landing probability. The coastal waters have good seawater dynamic conditions and strong marine self-purification capacity. The number of marine nature reserves, marine special protection areas and fishery germplasm resources protection areas in Shandong ranks the top in China. A good quality of offshore ecological environment can provide necessary support for the development of marine economy and the development of coastal tourism.

(5) Advantages of marine science and technology

Shandong takes the leading role in marine scientific research in China. It has 60 research and teaching units in marine fields at national and provincial level, 29 provincial and ministerial-level marine key laboratories. It also has 20 marine scientific research vessels, and 10 national-level marine scientific and technological demonstration group. Shandong also has 23 academicians belongs to Chinese Academy of Sciences and Chinese Academy of Engineering. Shandong’s marine scientific research results in key areas of designing marine environmental management, applied to marine environmental management in Shandong and China coastal area, as shown in Table 3-1.

(6) Marine industry in Shandong

Marine industry in Shandong has an important role in China, its marine economy is leading in China. The kinds of marine industry mainly include marine fishery production, seabed gold resources, proven reserves of marine oil and gas resources. With the continuous improvement of technical conditions, marine new energy development potential is huge, including marine wind energy, geothermal resources, tidal energy, wave energy and other new marine energy sources.

According to the data issued by Shandong Provincial Oceanic Administration (SPOA) in 2009, the total marine industry of Shandong reached 640 billion CNY, accounting for 18.9% of China's total marine production. The emerging industries such as marine biomedicine, marine new energy and coastal tourism developed rapidly, forming a relatively integral marine industry system. In 2016, the total value of marine production in Shandong reached 1.3 trillion CNY, an increase of 8.3% compare with last year.

In 2017, Shandong's total marine production value was 1.48 trillion CNY, accounting for 19.1% of China national total marine production and 20.4% of Shandong province's GDP, ranking second in China all provinces for many years; marine fisheries, marine biomedicine, marine salt industry, ocean power and marine transportation are the first position in China.

In 2018, Shandong's total marine production value was 1.6 trillion CNY, accounting for 18.5% of China national total marine production and 20.9% of Shandong province's GDP.

According to the Implementation Plan of the Ministry of Oceans and Fisheries of Shandong Province issued in 2018, by 2022, the total marine production value of Shandong Province will reach 2.3 trillion CNY, an average annual growth of more than 9%, accounting for about 23% of Shandong's GDP (SPOA, 2018).

3.2 Analysis of MEP in Shandong

3.2.1 Main MEP problems in Shandong

Marine Environment in Shandong lies in the relatively backward industrial structure and energy consumption structure. As for Energy structure, Shandong’s coal consumption is 409 million tons in 2015, as a result, the environment pollution is serious, brought direct and indirect challenges to MEP. During year 2011-2015, Shandong’s coal consumption accounted for about 8-11% of China’s total, as shown in Table 3-2 and Figure 3-2, this brought main air pollutant emissions ranked the first or the second in China. The premise of improving the MEP in Shandong is to effectively control land-based pollution. The urgent task in controlling land-based pollution is to significantly reduce coal consumption, adjust energy structure, reduce high-energy-consumption and high-pollution chemical industry, and Support the development of modern service industries such as finance and tourism.

3.2.2 Marine environment quality in Shandong coastal areas

(1) Overall situation of sea areas

According to the evaluation using China's seawater quality standard, the ratio of class I, class II, class III, class IV and inferior class IV is respectively 89.6%, 5.4%, 2.1%, 1.3% and 1.6% in 2018, the situation is generally similar with 2017(SPDEE, 2017; SPDEE, 2018).

(2) Coastal sea areas

The MEP in coastal sea areas had been polluted much, the ratio of class I, class II, class III, class IV and inferior class IV is respectively 27.7%, 61.5%, 4.6%, 0.0% and 6.2% in 2018.

(3) Seawater quality in different seasons in Shandong

In 2017 and 2018, the area of environmental monitoring in Shandong sea area is 159,500 km^2. The yearly averages sea area of Class IV and Inferior Class IV, which are seriously polluted, is 3789 km^2 in 2017, and the pollution area is serious in spring, as 5133 km^2.The value of these two indicators increased to 4669 km^2 and 5762 km^2 in 2018. The serious pollution area of coastal environment in Shandong had increased, as showed in Table 3-3. In 2018, Inferior Class IV seawater is mainly distributed in Laizhou Bay and the southern part of the Bohai Bay, the main indicator is inorganic nitrogen.

(4) Land-source pollution

In 2017, Shandong Province carried out a survey of land-source pollution into the sea, there are 294 land-source pollution sources in the Bohai Sea area in Shandong Province, including 30 sewage outlets into the sea, 39 rivers entering the sea, and 225 other kinds of water inlets into the sea. The polluted sea areas are mainly concentrated in bays with poor water exchange capacity, and the main pollutant is inorganic nitrogen.

In 2018, 76 direct-drainage industrial pollution sources and integrated sewage outlets were monitored, the total discharge of sewage was 778 million tons, the largest among the pollution indicators is COD as 233 million tons, accounting for 54% of the total directly discharge pollutants into the sea, followed by total nitrogen, followed by Total nitrogen is 7765 tons, accounting for 18% of the total amount of pollutants directly discharge into the sea.

(5) Sea areas adjacent to sewage outlets into the sea

In 2017, the monitoring of 14 sea areas adjacent to sewage outlets into the sea showed that, in May, seawater quality of 5 sea areas had not reach the water quality requirements for their due marine function. The main over-standard elements were inorganic nitrogen and BOD5. The monitoring results in August showed that, seawater quality of 3 sea areas had not reach the water quality requirements for their due marine function, the main over-standard elements were inorganic nitrogen and active phosphate.

In 2018, the monitoring of 12 key sea areas adjacent to sewage outlets into the sea showed that, the monitored in May implied that, seawater quality of 3 sea areas had not reach the water quality requirements for their due marine function. The main over-standard elements were inorganic nitrogen and phosphate, the monitored August implied that, the seawater quality of all sea areas meets the requirements of the functional area in which it is located.

(6) Eutrophication

Eutrophication is one of the main manifestations of MEP in Shandong offshore, the eutrophication area of seawater is different in different seasons. In 2017, the annual average is 3225 km^2. The most serious eutrophication happened in spring, the area is 4900 km^2, where the most eutrophic waters are concentrated in the coastal waters of the southern part of the Bohai Bay and the Laizhou Bay, as shown in Table 3-3.

(7) Red tide

According to the monitoring results of the nearest 10 years from 2008 to 2017, the red tide was found 24 times in Shandong coastal areas, as shown in Table 3-4. The main red tide is caused by a total of 10 dominant algae species (SPOA, 2017). From mid-March to early April 2017, two small-scale luminescent algae red tides were found in the Rizhao sea area.

(8) Green tide

In 2018, the Yellow Sea erupted a large-scale mossy green tide for the 12th consecutive year. On June 19, the moss green tide distribution area and coverage area reached the maximum and disappeared on August 13, 2018.

From May to July in 2017, a green tide occurred in the Yellow Sea in the southern part of Shandong Peninsula. On May 20th, the remote sensing satellite first discovered the green tide. From June to July, the green tide drifted to the north and northwest, and the area continued to expand, affecting coastal areas such as Rizhao, Qingdao, Yantai and Weihai. On June 19, the moss green tide distribution area and coverage area reached the maximum; the green tide entered the extinction stage in early July, and the green tide disappeared in late July. Compared with previous years, the occurrence and end of the green tide are earlier and the area is relatively reduced, as shown in Table 3-5. However, due to the overlap of the season of green tide is the same with tourism season, it directly affects the tourism development.

(9) Marine garbage

The amount of marine garbage in Shandong is mostly in the kinds of plastics, mainly from human activities on the coast. The density of coastal marine litter in Shandong is at a high level in China, and it is closely related to marine industry and tourist resort base in China.

Marine debris monitoring was carried out on 8 beaches and their adjacent waters in 2017.

The types of garbage included beach waste, floating debris on the sea and submarine waste. The distribution density of beach waste in the monitoring area is 37700/ha in 2017 (50200/ha in 2018) and the average weight is 15.4 kg/ha (8.31kg /ha in 2018).

The floating debris on the sea surface is mainly plastic, and the size is large and medium floating garbage. The distribution density is 2.67/ha in 2017 (4/ha in 2018), and the average weight is 0.33 kg/ha (0.51kg /ha in 2018).

The seabed garbage is mainly glass, with a distribution density of 4.44/ha in 2017 (8.89/ha in 2018) and an average weight of 0.73 kg/ha (0.92kg /ha in 2018).

3.3 Tourism as marine industry and its relation with MEP

3.3.1 Tourism industry of Shandong

As the positive progress of economic structure adjustment, the tourism industry is growing fast these years in Shandong, based on profound cultural resources, beautiful natural scenery, and coastal resort resources as a peninsula. Shandong is the hometown of Confucius, an internationally influential thinker. It has famous scenic spots such as Mount Tai and Yellow River, as well as famous coastal tourist cities as Qingdao, Yantai, Weihai and Rizhao, which have considerable international attractions. Because Shandong itself has a huge population, its location is close to Beijing, Shanghai and other major tourist source regions in China, with good aviation, railway, highway and port infrastructure system, both of Shandong's domestic and international tourism develop very quickly. It is becoming not only an important tourist source province, but also a tourist destination with good reception capacity, as shown in Figure 3-3 and Figure 3-4.

Select one city of Yantai in Shandong give further analysis. Yantai is a famous coastal tourist city and also famous for sea cucumbers. It is in the process of rapid industrialization, the proportion of the second industry is more than 50%, as shown in Figure 3-5, which brought many kinds of MEP problems. With the rapid tourism development, the proportion of the third industry is growing, tourism industry become an important part of marine industry, as shown in Figure 3-6, and the pressure of MEP is relatively reduced in recent years. Through strict marine environmental protection measures and laws implemented, the marine environment is much better than before.

3.3.2 Floating algae influence to beaches of Shandong

The problem of MEP has negative impacts on the development of tourism, the most typical one is floating algae influence to beaches of Shandong in recent years. In 2017, because of floating algae influence, 6 beaches in Shandong had been affected the number of days suitable for swimming during the tourist season. The worst situation is in Yan Da beach, during tourism season, 30% of the season is not suitable for swimming, indicating that MEP had directly affects the healthy development of coastal tourism. In 2018, the days of not suitable for swimming during the tourism season is over 35% in the Silver Beach in Rushan, as shown in Table 3-6.

3.4 Qualitative research on tourism and MEP in Shandong

3.4.1 Qualitative method based on stakeholder theory

A variety of qualitative analysis techniques, using multi-holders models, from different levels, different latitudes, different angles, attempts to find the detail state of the mutual influence between coastal tourism and MEP, so that to discuss the policy recommendations for comprehensive management of coastal economic development (especial coastal tourism) planning, which is in more perspective, scientifically and comprehensively thinking, and with more clearly, profoundly and more objectively useful to strengthen the marine environment management from central government to all levels of local government. It should try to explore a new way for the sustainable development to coordinate the economic growth and the marine environment in China’s coastal areas.

Officials from environmental management department as SPDEE said in an interview that, there is research evidence that, red tide may increase drawn by marine second industry growth, marine shipbuilding industry, and MEP may bring great change to the red tide area. The oil pollution and heavy metal pollution will bring severe challenge for the development of coastal tourism.

Marine environment protection and improvement depends on the efforts from government, industry and citizens, with different perspectives on environment pollution. Quantitative analysis provides accurate and accurate result through limited variables in the model, however, it is hard to get numeric instruments on environment policies and its implementation in China. Qualitative methods can catch multi-dimension information through further interview. In the field of policy research, qualitative method is frequently employed as a more deliberative, reflexive, and multidimensional approach to understand the perspectives, standpoints and roles of different stakeholders.

Stakeholder theory is applied in the assessment and policy research in multi-stakeholder contexts when governmental organizations, civil society, private sector and other parties involved in the policy making and implementation with different interests and priorities. Learning from Japan’s experience, the participants of national and local government, industry and public is very important in marine environment improvement (Kawashima, 1995), however, each stakeholder has their own cost-benefit during the pollution control and environment protection. To get further information from different stakeholders is fundamental for environment policy making and provide proper measures for policy implementation.

3.4.2 Qualitative research design

The qualitative method applied in this research is based on Stakeholder theory and employ the semi-structured interview and miner approach to dig the information, such as the ideas and knowledge exist within the interviewees, for qualitative analysis.

The interview conducted at province, prefecture and county level, prefecture Y and county C was selected.

Y is a prefecture-level city on the Bohai Strait in northeastern Shandong Province, south of the junction of Bohai Sea and Yellow Sea, a large fishing seaport in Shandong. The population was 6.968 million according to 2010 census, increased to 7.1218 million in 2018. Y is the second largest industrial city in Shandong, the GDP was 783.258 billion CNY in 2018. Y is a famous tourism attraction for its beach and Dan Cliffs which is the departure point of the Eight Immortals in Chinese myth.

Y administers 12 county-level divisions, including county C. County C is known for its sandy beaches and picturesque limestone cliffs. The total land area is only 56 square kilometers, the coastline is 146 km long. The population was 44025 according to 2010 census, decreased to 41714 in 2017 because younger generation migrants to Y and other cities. The major occupation of county C is aquaculture, producing products such as sea cucumbers, abalone, sea urchins, bivalves, kelp, scallops, and fish. Tourism is very important in county C, many of the villages manage resort hotels. The GDP of county C is 7.137 billion CNY in 2017.

The interviewees include: government officials at provincial, prefecture, county level from different government branches; managers and employees from tourism agency, hotel, and industry cooperation; coastal tourists and residents, as well as a teacher on environmental education. The detailed information of the interviewee as shown in Table 3-7.

For the officers at different level, the conversations cover the following questions: their ideas about the implementation of environment policy at local level and related obstacles; their knowledge about the relationship between economic development and environment protection; their understanding on coordinative development between environment and economy; their ideas on marine environment, etc. Besides the above questions, the follow-up questions, such as their ideas on the authority of environment branches among the government, and their comments on environment NGOs.

For the interviewees in business sector, the questions include: their understanding on environment protection; if their business affected by the environment protection policy and regulations, then, how the business changed/plan to meet the environment standard; etc.

For the tourists and residents, the questions include: their knowledge about the marine environment problems; their ideas about the relationship between coastal tourism and marine environment, etc. Follow-up questions are related to the interviewee's occupation.

3.4.3 Results from qualitative research

(1) Economic development taken as priority

In Shandong, environmental protection is still taken as a negative factor for economic development and job opportunity. Coastal economy (especially island economy) is much depended and relied on marine environment, but nearly no measures to protect marine environment at prefecture and county level.

Shandong approved its "blue economy" development strategy in 2011, is the first province in China to take a marine industry as a priority in economic development. We understand that marine industry, especially tourism and fishing is highly depended on marine environment. Frankly speaking, we did not take marine environment protection as a priority, the pressure from economic development is much bigger than environment protection. Green GDP is more like a slogan. (C)

Y is a coastal prefecture, marine industry accounts for a large proportion of GDP compared with other prefectures in Shandong. We benefit from the sea, we should pay back to sea through marine environment protection, but in fact, we didn't do well, we did not have enough measures for marine environment protection. (D)

We are famous for our beautiful island nature and sea cucumbers, the economy of the island is largely relied on fishing. Of course, we support the marine environment protection. I always introduce the good marine environment around our island in different speeches, like today, when we firstly met, I also welcome you to my beautiful homeland. Beautiful environment is the business card of this island. We did not invest any factories because of the concern for pollution control, it is hard for the young people to find a good job here, so, most of them choose to leave this island to mainland. We need to explore other business to develop our economy. So, we hope to attract more tourist to come, and take tourism as our pillar industry. (H)

(2) MEP is not concerned much as air pollution

Although marine environment management is the local government's duties, the local government did not pay much attention on MEP control compared with more obvious air pollution.

Shandong is located in Bohai Rim, and involved in couple of Bohai environment protection projects, such as Blue Bohai Project. Making planning on marine environment pollution control is one of our duties, we have a division "Watershed ecological environment management division" taking charge of making surface water and coastal environment protection planning, and key river basin and sea shore environment pollution control management. If you compared marine environment protection with air pollution control, air pollution control got more pressure from both the national government and the public, and get more attention from the deputy governor of whom is in charge of environment issues, marine environment is not concerned much at our daily work. But you know marine environment protection is not isolate from the land environment protection, what we have done on land-source pollution control will also bring benefit to marine environment. It might be far from enough for marine environment improvement, but, at least, the actions had started for preventing marine environment getting worse. (A)

BoE of Y prefecture: we have not our own environment policy and regulation, our responsibility is policy implementation. For marine environment, our responsibility is on guidance, coordination and monitory on the implementation of the planning on coastal area pollution control. However, the planning is very brief without detailed guidelines, we can't get strength measures for the implementation. (E)

(3) Lack of synthesis coordination among administrative bodies

Guidelines, cooperation, supervision coastal regional pollution prevention measures is one of the responsibility of Shandong Bureau of SPDEE, but it is not powerful enough for them to coordinate other government departments, and it is hard to let other government departments to put environment consideration in their policy making.

Xiaoqinghe is a river which is one of the rivers flowing into Bohai Rim. Shandong has established an office for Xiaoqinghe river treatment, and organized a working committee to involve environment, water resource, industry management, tourism and other related administrative branches as a member. The working committee have meetings at irregularly scheduled and gathered for investigation on the pollution control. However, the coordination among the member do not work well. Environmental branches is at the same level with other branches, we are not powerful enough to coordinate the other branches. (A)

I had participated an investigation along Xiaoqinghe last year. I grew up in a town not far from Xiaoqinghe, I know the water quality is terrible in 1980s and 1990s. Now, the water quality is much better than 1990s, but still far less than when I was young in 1970s. We are the members of the committee, but we just attend the meetings and investigations as a member, can't contribution much. (B)

(4) Weak industry's responsibility

Industry is a key stakeholder in environment protection, but only less enterprises recognized the important of environment protection, and only less enterprises take different perspective and position on environment protection.

I graduated from college in 2013. I built an aluminum factory with my classmates, supported by government loan and our family investment. The equipment is quite new and we put more investment on technology compared with other factories in the market. There is state-own aluminum enterprises shutdown couple years ago, we employed the technician retired from that enterprises, so the quality of our production is quite good. The market is just so-so in previous years, there are other small factories in same market producing low quality productions with low price. I know many factories was closed these two years because they cannot meet the environment standards, so we got more orders this year. My father used to operate a small wood-door factory that was forced to close last year for environment reasons. He complains the environment standard a lot at home, sometime he went to the factory at night to produce if he got an order from the old clients. (M)

I think we pay for the environment protection, such a sewage water treatment fee. Water use is a big cost for hotel, if there is good technology to save water, I would like to apply. Y is a coastal city, many tourists come in summer time, we support the marine environment protection to have more people come to enjoy. I know there are factories closed for environment reason, I have a housekeeper who used to work in a factory which closed last year. (K)

(5) Growing public awareness and environment education

The environment education is provided at formal education system in primary and secondary school, far from enough information provided at community.

The college entrance examination (gaokao in Chinese) is very important in China because not every student in middle school can get the opportunity to enter the college, so, to get a higher score is the target for the students (as well as for their family and school). China has involve environmental protection knowledge in the college entrance examination, but only as a selection part. It is still a huge progress in environment education. Everybody knows how important the gaokao is. We have environment protection in the selected part, the student has got many environment knowledges and know how to answer the related questions in examination. They are doing quite well in their daily life, such as saving water, this generation will perform better than their parents in environment protection. There is no marine environment knowledge in the current textbook, the students and teachers target on the score of gaokao, we do not have time to talk about the content that not covered by examination, although we live in coastal areas, and we do care about the marine environment. (Q)

I work in Beijing and came to Shandong for a business trip. Now I am a tourist to enjoy my weekend and will go back Beijing tomorrow night. I travel a lot every year, and find that the environment awareness of Chinese people improved, especially for young generation, they can understand the idea "Leave no trace". There are gaps if compare with other nations, like Japan. (N)

I am a swimming lover. I used to spend my summer vacation in Qingdao, I came here since 3 years ago because the terrible Hutai (red tide) in Qingdao. The water is much clear here, I come every summer since then. For marine environment protection, I know it is important. What can I do? I do not leave the garbage at the seashore. (O)

I live here since I was born. Many tourists come here in summer, they had not protected the environment as much as we do, they just stay here for couple days, and we stay here lifelong. In recent years, the seashore becomes clean, almost no people, including the tourist, to drop garbage into the sand and sea water. We welcome tourist because they bring us job opportunity and spend money here. We know where the tourists like to stay, we'd better choose other location to swim, and ovoid to swim in tourism rush hour. I think we have the capacity to host more tourist. (P)

3.4.4 Inspiration from qualitative research

Marine economy has drawn many attentions of policy makers in Shandong Province at different levels.

Compare with air pollution, MEP policy is concerned at provincial level, but did not pay much attention at prefecture and county level.

Coastal economy (especially island economy) is much depended and relied on marine environment, but nearly no measures to protect marine environment at prefecture and county level.

Coastal tourism is benefited a lot from good marine environment, with some concerns and measures for marine environment protection (help the tourist to get marine environment awareness, environment-friendly way in tourism management). Tourists have less environment awareness compared with local residence.

3.5 Summary

As a typical marine province in China, in terms of total population, GDP and marine industry, Shandong ranks at the forefront in China. So, the analysis of Shandong's MEP have reference value for other coastal areas of China.

The case study found the main challenges to MEP in Shandong. The industrial structure dominated by heavy chemical industry and the coal-dominated energy structure, and other high-energy-consuming industries had brought much land-based pollution emissions, all these will bring serious challenges to MEP directly or indirectly. The results of case study indicate that, during 2011-2015, the coal consumption of Shandong accounted for 8-11% of the total coal consumption in China. In recent years, large areas of green tides and red tides around Shandong coastal areas are serious consequences of MEP. The development of marine industry also may cause extensive utilization of marine resources, high intensity of exploitation of the seas and marine ecosystem functions decreasing, as a result, the marine ecological security status become worsening, etc.

Through the development of tertiary industry such as coastal tourism, the adjustment of economic structure is conducive to the governance of MEP. Through qualitative interviews with different local stakeholders proved that, the understanding and governance of MEP is a complex system, and its solutions must be promoted from the perspective of sustainable development.

In the long run, to solve the MEP problem, it need to promote positive interaction between the ocean and land both in economic development and environmental protection. Bring into play the peninsula's geographical advantage, integrate the ocean and land as a whole, co-ordinate the cultivation of advantageous industries. Control land-based pollution and reduce offshore pollution. Provide a strong foundation for improving land-based ecological environment to help to improve marine environment.

In addition to strictly implementing the relevant laws and regulations promulgated by China, Shandong had taken the lead in formulation and implementation with local laws and regulations focus on MEP. Through strict enforcement of regulations to stop the related problems of deteriorating marine environment and continuously improve the marine ecological environment. In the future, it is necessary to strengthen the comprehensive remediation and ecological restoration of the sea area, to make the overall situation of seawater environmental quality in the coastal waters better.

Based on a good peninsula marine ecological environment, it needs to speed up the course of transforming MEP solution from the passive stage of pollution prevention to the building a beautiful coastal living environment, and enhance public service capabilities, create a livable and stable, harmonious coastal sea area. In this way, Shandong can integrate the culture, sports and tourism industries, based on the international influence of Qingdao international Beer Festival and Yantai international Wine Festival, Shandong can gradually form the brand influence as an international tourism destination.

Table 3-1 List of the important marine scientific research and educational units in Shandong

1	China National Laboratory for Marine Science and Technology in Qingdao
2	Institute of Oceanology, Chinese Academy of Sciences
3	First Institute of Oceanography, State Oceanic Administration of China
4	China Ocean University
5	Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences
6	Qingdao Institute of Marine Geology, Natural Resources Ministry of China
7	Yantai Coastal Zone Research Institute, Chinese Academy of Sciences
8	Institute of Bioenergy and Process, Chinese Academy of Sciences
9	China National Deep Sea Base
10	China Marine Science Comprehensive Investigation Ship
11	Yantai Institute of Marine Engineering, China International Marine Container Co., Ltd. (CIMC)
12	Qingdao National Marine Science Research Center
13	Shandong Nuclear Power Research Institute, Haiyang Branch
14	Yellow River Delta Institute of Sustainable Development
15	Shandong Institute of Marine Chemical Science in Planning and Construction
16	Shandong Ocean Ship Research Institute
17	China National Ocean New Energy Research Institute
18	China National Research Center for Salt-tolerant Plants and Wetlands

Resource: China State Council, 2011.Shandong Peninsula Blue Economy Development Planning,

Table 3-2 Shandong's raw coal consumption and percentage in China, 2011-2015

	2011	2012	2013	2014	2015
China (ton)	342950	352647	424425	411613	397014
Shandong (ton)	38921	40233	37683	39561	40927
Shandong/China (%)	11.3	11.4	8.9	9.6	10.3

Data Source: NBS of China.2011-2015. CSY.

Table 3-3 Area of different quality of sea water in Shandong in 2017 and 2018 (km^2)

		Class I	Class II	Class III	Class IV	Inferior Class IV	Eutrophication
March	2017	140463	11165	2739	1046	4087	4900
	2018	142313	7413	4012	2862	2900	6824
May	2017	144708	8515	3543	1206	1521	1399
	2018	145672	3420	5890	2630	1888	1942
August	2017	143965	6098	2985	1921	2531	2865
	2018	137312	16875	1788	1131	2394	3253
October	2017	143595	8657	4409	1112	1727	3735
	2018	145946	6670	2011	1538	3335	4420
Average	2017	143683	8609	3419	1321	2468	3225
	2018	142811	8595	3425	2040	2629	4110

Note: Class I adapted to marine fisheries waters, marine nature reserves and cherish endangered marine life reserves; Class II adapted to aquaculture areas, bathing beaches, marine sports or recreational areas where the human body is in direct contact with sea water, and industrial water areas directly related to human consumption; Class III adapted to the general industrial water area, coastal scenic tourist area; Class IV adapted to marine port waters, marine development operations.

Data Source: Shandong Provincial Department of Ecology and Environment (SPDEE), 2017 and 2018. Shandong Province Marine Ecological Environment Bulletin (SPMEEB)

Table 3-4 Frequency and area of red tide in Shandong (2008-2018)

	Frequency	Coverage area (km^2)
2008	0	0
2009	6	1344.8
2010	3	12.5
2011	1	Not gathered
2012	5	805.4
2013	3	80.0
2014	4	909.0
2015	0	0
2016	0	0
2017	2	0.00092
2018	0	0

Source: SPDEE, 2008-2018. SPMEEB.

Table 3-5 Maximum distribution and coverage areas of green tide in Shandong

	Maximum distribution area (km^2)	Maximum coverage area (km^2)
2013	29733	790
2014	50000	540
2015	52700	594
2016	57500	554
2017	26726	270
2018	26850	150

Source: SPDEE, 2013-2018. SPMEEB.

Table 3-6 Floating algae influence to swimming in beaches of Shandong in 2017 and 2018

	Not suitable for swimming days during tourist seasons (%)		Polluted reasons
	2017	2018	
Golden Beach (Yantai)	18	13	Floating algae
No.1 Beach (Yantai)	25	27	Floating algae
Yan Da (Yantai)	30	19	Floating algae
Silver Beach (Rushan)	22	35	Floating algae
Ten thousand meters (Haiyang)	17	2	Floating algae
Stone old man(Qingdao)	15	26	Floating algae

Data source: SPDEE, 2017 and 2018. SPMEEB.

Table 3-7 List of the qualitative research interviewee

Title	Affiliation	Type	Code*
deputy director	Bureau of Environment (BOE)	Official	A
deputy director	Bureau of Tourism (BOE)	Official	B
division chief	Development and Reform Committee (DRC)	Official	C
deputy Mayor	Y prefecture	Official	D
director	Bureau of Environment, Y prefecture	Official	E
director	Bureau of Tourism, Y prefecture	Official	F
division chief	DRC, Y prefecture	Official	G
deputy mayor	C county	Official	H
manager	Tour agency	Industry	I
guide	Tour agency	Industry	J
manager	Hotel	Industry	K
Entrepreneur	Aluminum manufacturer	Industry	M
Tourist	Foreigner	Foreigner	N
Tourist	Chinese	Citizens	O
Resident	Retired	Citizens	P
Resident	Middle school teacher	Citizens	Q

* Represents the code of the different interviewees in the following interview records

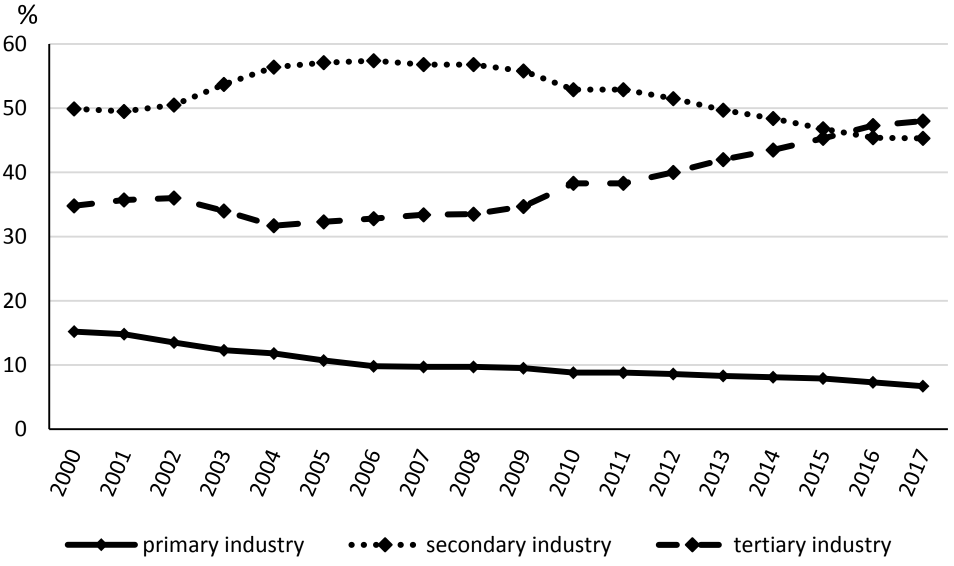

Figure 3-1 Industry structure of Shandong, 2000-2017

Data Source: NBS of China. 2000-2017. CSY.

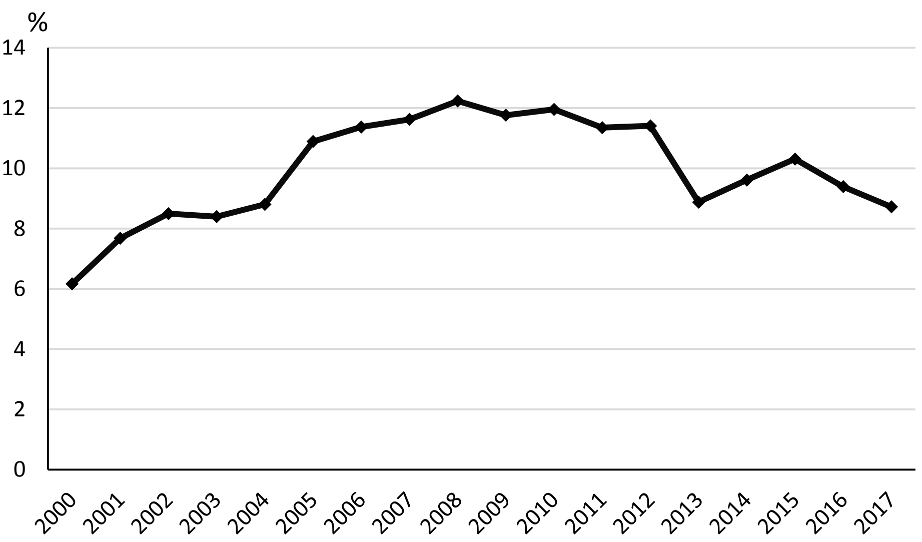

Figure 3-2 Coal assumption of Shandong in China, 2006-2017

Data Source: Coal Industry Information Center of China, 2006-2017

Figure 3-3 International tourism development of Shandong, 1981-2014

Source: Shandong Provincial Statistics Bureau, 1981-2014, Shandong Statistic Yearbook.

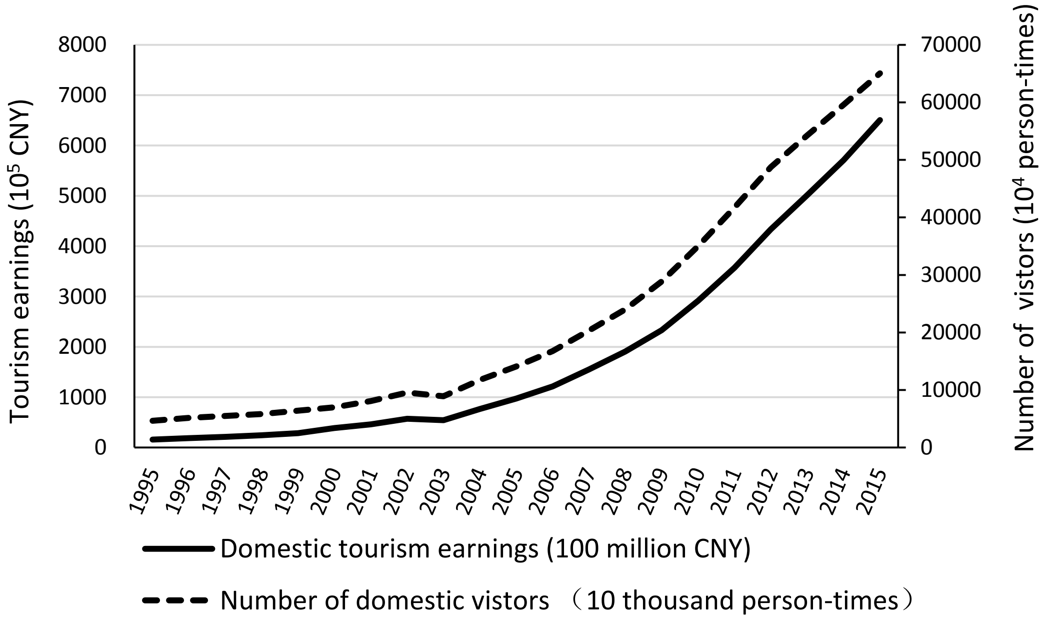

Figure 3-4 Domestic tourism development of Shandong, 1995-2015

Source: Shandong Provincial Statistics Bureau, 1995-2015, Shandong Statistic Yearbook.

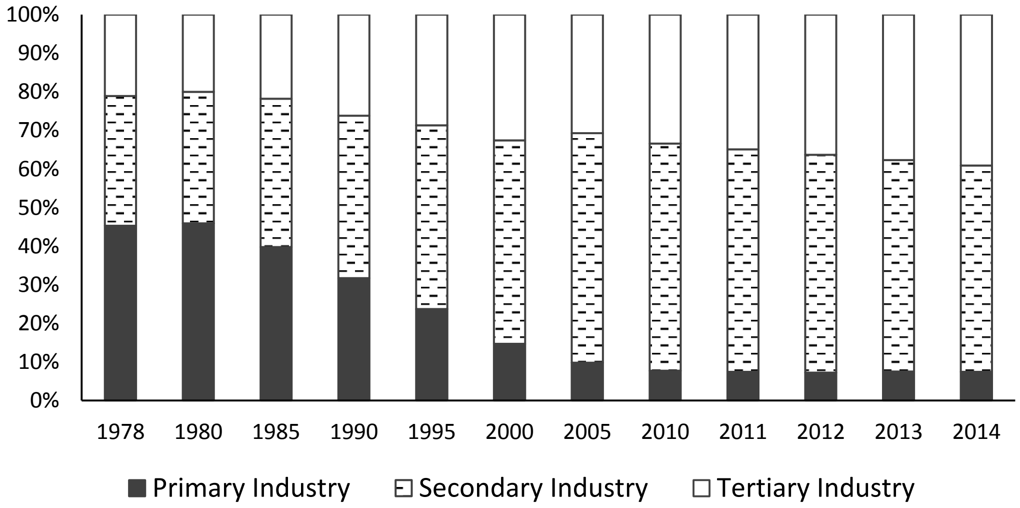

Figure 3-5 Industrial structure of Yantai in Shandong, 1978-2017

Source：Yantai Statistics Bureau. 1978-2017.Yantai Statistics Yearbook.

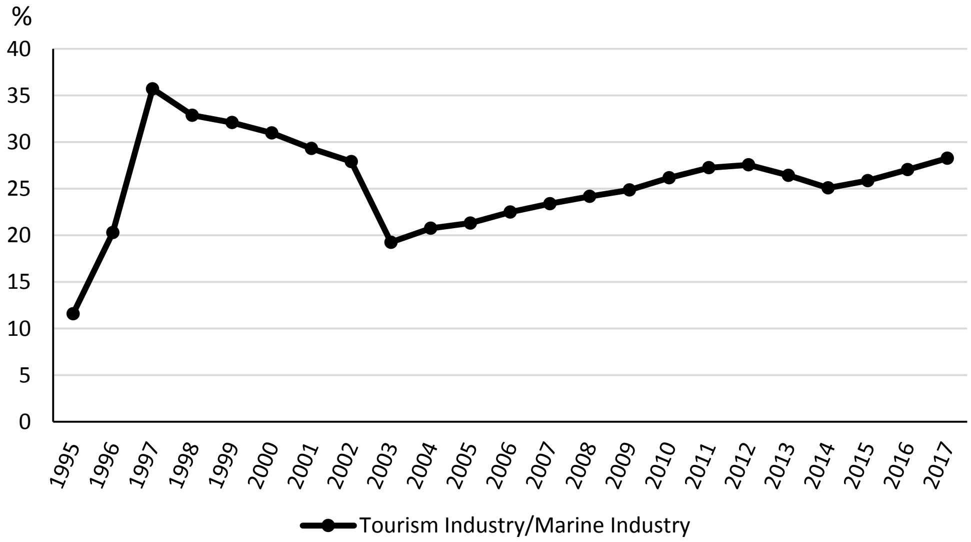

Figure 3-6 Tourism as the marine industry in Yantai of Shandong, 1978-2017

Source：Yantai Statistics Bureau. 1978-2017.Yantai Statistics Yearbook.

Chapter 4 Comparative Study on MEP Management between China and Japan

Both China and Japan are facing the challenges of MEP, Japan had faced this problem earlier, study the experience of Japan focus on MEP management is a practical reference to China. The "Thirteenth Five-Year Plan for China Economic and Social Development" emphasized the national strategy of developing the marine economy (CSC, 2016), so, the MEP issue in China requires more attention from all parties in China and also from international perspective.

As a traditional marine country, Japan keeps committing to the development of marine resources and the protection of marine environment. During the rapid industry development in the 1960s and 1970s, Japan had responded to severe challenges from MEP, which is of great reference to China.

The research chose Japan as a reference, focus on MEP management, Compare China and Japan’s administrative mechanism, laws, plans, standards and public participation.

4.1 Administration mechanism of marine management

4.1.1 Japan's marine environmental administrative system

(1) The Headquarter of Ocean Policy (HOP)

The Basic Act of Ocean Policy (BAOP) required to establish the HOP in the Cabinet. The Headquarter was established the same day as the BAOP issued on April 20, 2007 (Government of Japan, 2007).

The team of HOP consists of Director-General, the Vice Director-Generals and Members of HOP. The HOP is headed by the Director-General served as Prime Minister. The Chief Cabinet Secretary and the Minister for Ocean Policy serve as the Vice Director-Generals of the HOP, and the Members of HOP are also assigned with all Ministers of the State.

The responsibilities of the HOP include: (i) Drafting and promotion of execution of Basic Plan on Ocean Policy (BPOP); (ii) Synthesis coordination for measures of implementation by relevant administrative bodies based on BPOP; (iii) Planning and drafting of important measures with regard to the oceans as well as synthesis coordination.

(2) Environment and related ministries with responsibilities on marine environment

Japan Environment Agency (JEA) was the national environmental management authority since 1971. The Central Environment Council, the top advisory panel of JEA, whose membership includes many non-governmental experts, played an important role in developing the environment plans, as well as reviews progress reports from various ministries implementing the plans. Environmental concerns are also part of the annual national budgeting process. As a result of Japan government reform, Ministry of Environment (MoE) was formed in January of 2001, taking the responsibility of JEA.

Besides MoE, other ministries also took the environmental management responsibilities, include:

– Ministry of Foreign Affairs (MOFA): diplomatic policy and negotiations relating to global environmental issues.

– Ministry of Agriculture, Forestry and Fisheries (MAFF): management of natural forests, conservation of fishery resources, promotion of sustainable agriculture, regulation of agricultural chemicals.

– Ministry of Economy, Trade and Industry (METI): promotion of energy conservation, development of technology for industrial pollution prevention and control, recycling of industrial waste.

– Ministry of Land, Infrastructure and Transport (MLIT): control of pollution from road vehicle development of public works (e.g. sewerage, urban parks and roads), restoration of rivers, prevention of coastal zone pollution of these measures.

4.1.2 China's marine environmental administrative system

China's current management of marine space and ecological environment mainly involves four departments of the State Council of China (SCC)：the core management functions of marine land and space belong to the State Oceanic Administration (SOA); the functions of marine ecological environment management belong to the Ministry of Ecology and Environment (MEE); marine fisheries and their ecological environment management belong to Ministry of Agriculture and Rural Affairs (MARA); the management of maritime traffic and port ecological environment and security incidents belong to the Ministry of Transportation (MT).

(1) SOA

State Oceanic Administration (SOA) published Bulletin on China's Marine Ecological Environment (CMEE) every year before 2018. According to the latest arrangement set up by SCC in August 2018, Ministry of Natural Resources (MNR) also retained the “SOA” brand.

The main duties related to marine resources and ecological environment management are as following:

-Control the utilization of nation owned marine space and resources. Formulate laws and regulations related deep seas, formulate and implement the annual utilization plan for marine resources. Responsible for the management of land use in sea areas and islands, in charge of protection on marine ecology, sea area coastline and island restoration.

-Cooperate with relevant departments to formulate plans and policies for marine economic development, comprehensive protection and utilization of coastal zones, and supervise implementation. Promote the development of marine industries such as seawater desalination and comprehensive utilization, marine renewable energy.

- Responsible for the management of geographical names of non-resident islands, sea areas and seabed topography, and formulate measures for the management of special-purpose islands and supervise their implementation.

-Responsible for marine observation and forecasting, early warning monitoring and disaster reduction, and participate in emergency response to major marine disasters.

- Formulate policies for ocean observation and marine science surveys. Conduct marine ecological early warning and monitoring, disaster prevention, risk assessment and hidden danger investigation, issue alarms and bulletins. Construction the national ocean observing network to organize marine science surveys. Participate in the emergency disposal of major marine disasters.

(2) MEE

Ministry of Ecology and Environment (MEE) is the main department of China's environmental protection (including marine environment). Before 2017, MEE published Bulletin on Environmental Quality of China's Coastal Waters (BEQCCW) every year. From 2018, CMEE was issued by MEE, and the contents of BEQCCW was also included in the new version CMEE.

The main duties related to marine environment management are as following:

-Supervise the implementation of ecological environment planning and water function zoning in key areas, river basins, sea areas, drinking water sources. Formulation of ecological environment standards, ecological environment benchmarks and technical specifications.

-Coordinate and resolve environmental pollution disputes across different regions, river basins and sea areas.

-Formulate and supervise the implementation of total pollutant discharge control and discharge permit system for land and sea, determine the air pollution capacity of the atmosphere, water and ocean, and control indicators of the total amount of pollutants to be supervised.

-Formulate pollution prevention and management systems for the atmosphere, water, ocean, soil, etc. and supervise their implementation. Promote pollutant emission reduction tasks in various places.

-Responsible for ecological environment monitoring. Formulate ecological environment monitoring systems and regulations, formulate relevant standards and supervise implementation.

-Participate in the work related to global marine ecological environment governance.

(3) MARA

Ministry of Agriculture and Rural Affairs (MARA) of China is responsible for the supervision and management of marine fishery, including for international double multilateral fisheries negotiations and implementation, undertake the handling of major foreign-related fishery disputes. Responsible for the management of offshore fisheries and the supervision of fishing ports. Formulate fishery development policies and plans, protect, rationally develop and utilize fishery resources, organize the prevention of aquatic and plant diseases. Maintain the national fisheries rights of the national marine and freshwater jurisdictions. Organize the ecological environment of fishery waters and the protection of aquatic wildlife. Supervise the implementation of international fisheries treaties, guide the safe production of fisheries.

(4) MT

The responsibility of Ministry of Transportation (MT) in China includes water traffic safety supervision. Responsible for water traffic control, inspection and registration of ships and related water facilities, pollution prevention, water fire protection, maritime security, salvage, communication and navigation, as well as for ship and port facility security and supervision of dangerous goods transportation. Responsible for the emergency handling of water traffic safety accidents in the central management waters, pollution accidents of ships and related water facilities.

4.1.3 Comparison in marine management between China and Japan

Japan, as a traditional maritime country, has a relatively strong national-level coordination structure for marine environmental protection, and can coordinate the implementation of policies and regulations of various departments related to the marine environment, Japan's marine environmental management system has many references to China.

China is lack of synthesis coordination and measures of implementation by relevant administrative bodies. From Japan’s experience, it is important to coordinate the related government branches in marine environment protection. There are many departments designing marine environment in China, the coordination mechanism at the national level needs to be established. Based on the experience of Japan, China needs to strengthen the coordination mechanism of MEP at the national level, so as to realize the effectiveness and sustainable development of the management of marine ecological environment.

4.2 Marine environmental laws and their implementation

4.2.1 Laws related to marine environment management in Japan

(1) A comprehensive legislation system for environment protection

Japan had built a comprehensive legislation system for environment protection. An extensive number of laws had played and are playing key roles in marine environment protection. As to water-related laws, specific law dealing with special aspect of water management.

Water Pollution Control Law which issued by JEA in 1970, provides for effluent limits and set pollution reduction targets in designated watersheds, and designate important areas for domestic wastewater measures, promote plans for domestic wastewater management.

Law Concerning Special Measures for Conservation of the Environment of the Seto Inland which issued by JEA in 1978, provides additional measures applying to the drainage basin of the Seto Inland Sea and its natural shores.

All the laws form a legislation system of applicable rules and special measures aimed at particular issues and areas, such as enclosed or semi-enclosed water bodies. Among them, the Basic Environment Law (BEL) and The Basic Act of Ocean Policy (BAOP) are fundamental laws on marine environment.

(2) Basic Environment Law (BEL)

The Basic Law for Environmental Pollution Control (BLEPC) which enacted in 1967, and the Nature Conservation Law which enacted in 1972 worked successfully in combating serious industrial pollution and to preserve the natural environment. After amended in 1970, the BLEPC requested the involvement of industry, national and local government, and citizens in respect to environment pollution.

On November 13, 1993, the BEL took effect as new comprehensive environmental management framework. The primary objective of the law is to protect the environment, by recognizing it as the essential life-support system to be passed on to future generations. This law targets on building a society that is economically sustainable without stressing the environment, and contributing positively to the conservation of the global environment. The national and local governments, corporations, and citizens all have the responsibilities.

Three basic propositions are introduced under BEL: i) utilize and conserve environmental resources to allow future generations to continue to do so; ii) build a society to allow for sustainable economic growth and generates low environmental loads; and iii) promote global environmental conservation through international co-operation.

BEL provides possibility for designating specific areas Basic Environment Plan.

(3) The Basic Act of Ocean Policy (BAOP)

The Basic Law system in Japan is especially useful for facilitating effective coordination in multifaceted policy areas. It involves the different ministries overseeing marine environment as well as other maritime affairs. In 2006, a multi-partisan basic ocean law study group which consisted of 10 political leaders, scholars and experts in various ocean fields, and observers from relevant government ministries and agencies worked on establishing a basic framework and mechanism to cope with the comprehensive ocean management. The BAOP went to effective in July 20, 2007. BAOP aims to "contribute to the sound development of the economy and society of our State, and to improve the stability of the lives of citizenry as well as to contribute to the coexistence of the oceans and mankind".

The general provisions, basic plan on ocean policy, basic measures, headquarter for ocean policy is the 4 chapters in BAOP.

In chapter 1, the Act highlights the rules of the development and use of the oceans with the conservation of marine environment, especially sound development of ocean industries. It requests a comprehensive governance of the oceans and legislative measures, and clarify the responsibilities of the State, the local government, business operators and the citizens, and require the coordination and cooperation in mutual communication among the relevant parties.

In chapter 2, the Act requires the government to formulate the Basic Plan on Ocean Policy (BPOP) to promote measures with regard to the oceans comprehensively and systematically, and to take necessary measures for the smooth implementation of BPOP.

In chapter 3, the Act provides detailed basic measures on promotion of development and use of ocean resources, conservation of marine environment, promotion of development of exclusive economic zone, promotion of ocean industries and strengthening the international competitiveness, integrated managing of the coastal zone, and enhancement of citizen's understanding of the oceans. These measures are highly important on protecting marine environment in the meantime of promoting the economic development.

In chapter 4, the Act provides detailed requirement on Headquarter for ocean policy, including establishment, affairs under the jurisdiction, organization, Director-General, Vice Director-General and members of the HOP, as well as the relevant ministers.

4.2.2 Laws and regulations on marine environment in China

In order to deal with various MEP problems, China had issued many laws and regulations as following:

-Regulations on Environmental Protection Management of Offshore Oil Exploration and Development. CSC. 1983

-Regulations on the Prevention and Control of Marine Environmental Pollution Caused by Pollution from Land-Based Pollutants. CSC, 1990

-Fisheries Act of PRC, Standing Committee of China National People's Congress (SCCNPC), 2000

- Law of the PRC on the Administration of Sea Areas. SCCNPC, 2001

-Regulations on the Prevention and Control of Marine Environmental Pollution from Marine Engineering Construction Projects. CSC, 2006

- Island Protection Law of the PRC. SCCNPC, 2010

- Environmental Protection Law of the PRC. SCCNPC, 2015

- Law on the Exploration and Development of Resources in Deep Seabed Areas, 2016

-Water Law of PRC. SCCNPC, 2016.

-Marine Environmental Protection Law of PRC. SCCNPC, 2017

-Water Pollution Prevention and Control Act, SCCNPC, 2017,

-Regulations on the Prevention and Control of Marine Environment by Ship Pollution. CSC, 2017

-Marine Dumping Management Regulations. CSC, 2017

Although China had enacted a large number of laws and regulations on marine environment, but, due to lack of national basic law on marine environmental protection, and lack of specific legal restrictions, and also coupled with lax enforcement and repetitive conflicts between multiple laws, the operability of implementation of laws and regulations is relatively poor, So, the law of marine environmental protection needs to be promoted through comprehensive legislation at the national level. At the same time, efforts must be made to strengthen the law enforcement inspectors and gradually solve the general problems of non-compliance with laws and lax enforcement.

4.2.3 Improvement on the implementation of laws on MEP in China

Now, China had adopted many marine conservation measures facing MEP, including legislation for marine pollution, environmental protection moratoriums, establishing marine protected areas systems, and add funds on marine research and protection. But, facing the driving force of economic development, the laws are often poorly implemented, some items of China’s marine environmental protection laws are just in general specification, items of the law and regulations are not comprehensive or strict in details, and difficult to be effective in implementation.

4.3 Marine environmental plans and its implementation

4.3.1 Major plans for environmental management in Japan

(1) The Basic Environment Plan (BEP)

BEP was drawn up in December 1994 based on the BEL. The plan maps out the basic approach of environmental policies with the mid-21st century in view and identifies 4 long-term objectives and sets the direction of measures to be implemented by the early 21st century for achieving these objectives.

The aim of Japan's first BEL (1994-2000) established the framework for a "sustainable society". Endorsed by the Cabinet, the plan sought to establish a socio-economic system based on 4 long-term objectives. The 4 long-term objectives include: i) a "sound material cycle", with a reduced environmental footprint for consumer products and with high resource efficiency and recycling; ii) harmonious coexistence with nature, including conservation of ecosystems and species, and assured access to outdoor recreation; iii) proactive public participation in environmental conservation activities; iv) active co-operation with international efforts for environmental conservation.

(2) Basic Plan on Ocean Policy (BPOP)

Based on Basic Act on Ocean Policy (BAOP) issued in 2007, the first BPOP was approved in March, 2008 to promote and co-ordinate the ocean measures, the second BPOP was approved in April 2013, and the third one was approved in May 2018. The three 5-years plan took critical role in Japan's ocean policy.

The first BPOP targeted on three objectives, taking the initiative in coping with panhuman issues in the sea; sustainable use of abundant marine resources and marine space; and contribution in the marine-related fields for realizing safe and secure lives of the citizenry.

This BPOP provided 6 detailed basic policy of measures with regard to the sea, including: (i) harmonization of the development and use of the sea with the preservation of the marine environment; (ii) securing the safety and security of the sea; (iii) enhancement of scientific knowledge of the sea; (iv) sound development of marine industries; (v) comprehensive governance of the sea; (vi) international partnership with regard to the sea. The Plan highlight the measures that the government should take comprehensively and systematically with regard to the sea.

The second BPOP based on the evaluation on the implementation of the first BPOP and the social-economic changes, add one more measure "improvement of marine-related education and heightening the understanding of oceans" besides continue to take the 6 basic policy measures as the first BPOP. The second plan involved the same main fields related to measures that the government should take comprehensively and systematically with regard to the sea, and paid more attention on marine energy use.

The third BPOP recap of 10 years progress from the enactment of the BAOP, facing the new social-economic situation and challenge toward get into a new oceanic state. The main measures include: use ocean more for the purpose of industries; maintain and protect the maritime environment; improve scientific knowledge; promote Arctic policy; international collaboration and cooperation; develop human resources with knowledge of ocean and advance citizens' understanding on ocean.

4.3.2 Plans for environment and marine protection in China

The main plans that have been issued focus on MEP by China are as following:

-National Ocean Development Plan. State Oceanic Administration (SOA), 1995

-China Ocean 21st Century Agenda. SOA, 1996

-National Marine Economic Development Plan Outline. National Development and Reform Commission (NDRC), SOA, 2003

-National Ocean Business Development Plan. CSC.2008

-National Twelfth Five-Year Plan for the Development of Marine Industry. NDRC, SOA, 2012

-National Marine Functional Zoning Plan (2011-2020). CSC, 2012

-National Marine Main Functional Area Planning. CSC, 2015

-National Science and Technology for Rejuvenate the Ocean Planning (2016-2020). Ministry of Science and Technology, SOA, 2016

-The 13th Five-Year Plan for National Marine Economic Development, NDRC, SOA,2017

There are many marine environment plans enacted by China already, however, due to the large number of governmental departments involved in the formulation and implementation of these plans, the contents of different plans had not been effectively integrated, which led to the lower effectiveness and discontinuous of the implementation for some of the plans.

4.3.3 Develop and implement national ocean plans of China

Studying the 3 plans of BPOP that had been issued by Japan, they have good continuity and are implemented by the Japanese cabinet, which can safeguard the planning implement efficiency. China needs to formulate and implement a more comprehensive marine environmental protection plan referred by the experience of Japan, the plan should be implemented by the central government. Through implement effective ocean plans to realize marine spatial utilization management. Promote marine functional zoning plan, develop resources and protect ocean by spatial plan. All kind of marine plans should be revised according to the latest situation and actual needs.

4.4. Comparison of seawater quality standards

Although the principles, methods and scientific basis for the formulation of seawater quality standards in various countries is somewhat different, but all the standards focus on protecting human health and ecological balance. The core content of seawater quality standards published by coastal countries in the world can be summarized into three aspects: health, aquatic life protection and general landscape.

4.4.1 China's surface water and seawater quality standards

According to the incomplete statistics on the standards issued by MEE of China, there are currently more than100 standards for water environmental protection in China, of which two core standards are closely related to MEP.

(1) Environmental quality standards for surface water (EQSSW, GB 3838-2002)

EQSSW was issued by China's State Environmental Protection Administration (now is replaced by MEE) in 2002, mainly used for land surface water. This standard specifies the items and limits that should be controlled by water environment quality according to the functional classification and protection objectives of surface water environment, and is applicable to the surface waters of rivers, lakes, canals, channels and reservoirs in China.

(i) Monitoring indicators of EQSSW

Basic indicators of surface water environment: total of 24 monitoring indicators;

Supplement indicators for concentrated drinking surface water source: total of 5 monitoring indicators;

Specific indicators for the surface water source of concentrated drinking water: total of 80 monitoring indicators.

(ii) Classification of surface water environmental quality

The water quality of rivers entering the sea in China refers to EQSSW. According to the environmental function and protection target of surface waters, it is divided into five classes, Class I as the best, Class V as the worst. Corresponding to the five classes of water functions of surface water, the standard values of corresponding environmental monitoring indicators are respectively implemented (see Appendix 1):

Class I: applicable to source water and national nature reserves;

Class II: applicable to the first-grade protection zone of concentrated drinking water surface water source;

Class III: applicable to the secondary protection areas of centralized drinking water surface water sources;

Class IV: suitable for general industrial water use areas and recreational water areas where the human body is not in direct contact with water;

Class V: agricultural water areas and general landscape waters.

For Class I ~V of surface water, the indicators are divided into 5 classes, and the different classes respectively implement the standard limit values.

(2) Sea water quality standard (SWQS, GB 3097-1997)

(i) Monitoring indicators of SWQS

SWQS specifies the water quality requirements for various types of functions in the sea. The standard was published in 1982 and revised in 1997 by MEE.

The main environmental indicators adopted by this standard include: suspended matter, floating matter, color, smell, taste, pH, chemical oxygen demand (COD), dissolved oxygen (DO), water temperature, coliform, pathogen, sediment and harmful substances.

The following 15 indicators define the maximum allowable concentrations: mercury, cadmium, lead, total chromium, arsenic, copper, zinc, selenium, oils, cyanides, sulfides, volatile phenols, organochlorine pesticides, inorganic nitrogen (IN) and inorganic phosphorus (IP); IN and IP are mainly used to evaluate the limit value of the occurrence of "red tide" in some sea areas.

(ii) Classification of SWQS

According to the different functions and protection objectives of the sea area, the sea water quality in China is divided 4 Classes refers to SWQS, Class I as the best, Class IV as the worst.

Class I: adapt to marine fisheries waters, marine nature reserves and cherish endangered marine life reserves.

Class II: adapted to aquaculture areas, bathing beaches, marine sports or recreational areas where the human body can direct contact with sea water, and industrial water areas directly related to human consumption.

Class III adapt to the general industrial water area, coastal scenic tourist area.

Class IV: adapted to marine port waters, marine development operations.

There are 35 indicators for SWQS, the standard values of corresponding sea water class environmental monitoring indicators are respectively implemented (see Appendix 2).

4.4.2 Japan's surface water and sea water quality standards

(1) The history and rules of Japan's marine environmental standards

During the process of rapid economic development in the past, with the rapid development of industrialization, pollution incidents occurred frequently, and the public hazard problem had become increasingly, marine environmental monitoring and protection items also began to be paid attention to.

The formulation principles of environmental quality standards have clear legal provisions by Japan's Basic Environment Law (BEL), the definition of “water class” involved in the formulation of environmental quality standards and quality standards, the standard revision and standard implementation requirements are clearly defined as follows:

(i) The government establishes environmental quality standards; it mainly has two functions of protection for human health and protection of the living environment;

(ii) The “water class” involved in the environmental quality standards by the government, that is, the class of area divided by rivers, lakes, and sea areas, according to different water resources utilization purposes, this is similar to China's waters functional areas, the standard values for different water classes are different.

(2) Japan's surface water environmental quality standard system

The BEL of Japan establishes 2 kinds of Environmental Quality Standard (EQS) relating to water pollution: “environmental water quality standards for protecting human health”; “environmental water quality standards for protecting the living environment” (MoE, 2018).

(i) Standards for protecting human health

There are 26 items for protecting human health items belong to the strictly monitored and controlled by the state according to laws and regulations. The monitoring frequency is often, and it must be kept up to standard at any time for protecting human health. Additionally, 27 other items have been added as “substance items for monitoring” when further observation when needed.

(ii) Standards for protecting living environment

The living environment indicators refers to the monitoring items of the living and ecological environment closely related to human life. The living environment items also falls within the scope of national quality standards, but it allows for the progressive management and prevention of pollutants through measures for a period to compliance to the standard.

(iii) Water quality classes system

According to the basic 5 items of the standard for the living environment, the water quality of rivers and lakes are divided into 6 classes: AA, A, B, C, D and E.

The quality of lakes (natural lakes and reservoirs that have 10 million m3 or more) are divided into 4 classes: AA, A, B, C.

Based on the item of “total zinc” standard values, according to the “adaptability to aquatic life habitat conditions”, the classes of rivers and lakes water are divided 4 classes: Aquatic life

A, Special aquatic life A, Aquatic life B, Special aquatic life B.

According to the total nitrogen (TN) and total phosphorus (TP) standard, water environmental quality of the lakes is divided into 5 classes: I, II, III, IV and V.

(3) Sea water quality standards and classes system

Based on the 5 indicators as monitoring items for protecting living environment (sea waters): pH, COD, DO, Total Coliform and N-hexane Extracts (oil, etc.), according to the different standard values of above 5 indicators, sea water is divided into 3 classes: A, B, and C.

In order to prevent eutrophication in the sea area, total nitrogen (TN) and total phosphorus (TP) were added to the standard. According to the different standard values of above two indicators, sea water was divided into 4 classes: I, II, III and IV.

The total zinc index was added from the perspective of protecting aquatic organisms; according to the different standard values of "Total zinc" indicator, the sea water is divided into 2 classes: Class A organisms, Special Class A organisms.

4.4.3 Comparative analysis

(1) Environmental standards for land surface water and sea areas should be interconnected

Standards are important scientific and technological support for water environment management. The environmental quality standard system structure of sea water in Japan is consistent with the Japanese surface water environmental quality standard system, although the specific content is different.

China's surface water environmental standards and sea water marine environmental standards have not yet been linked to each other within a consistent standard system. There are some problems between the two standards, the water quality classification indicators are not connected, the analysis methods of some indicators are different, and the standard limits of some indicators are unscientific (Yang et al, 2018).

Refer from Japan's experience, China can try to realize the integration of the two standards gradually, strengthen the connection between the two environmental standards of surface water and seawater. The water quality standard research should be strengthened, start water quality standards revision as soon as possible, pay more attention to health, safety and other related indicators, strengthen the control of toxic and harmful pollutants, and make water environmental quality standards better serve water environmental protection.

(2) Standards implemented in Japan are generally stricter than China

(i) Surface water environmental quality standard

The control values of several core indicators of surface water environmental quality in Japan are usually more stringent than those implemented in China, for example, the indicator of COD is very clear as shown in Table4-1.

(ii) The minimum detection value of surface water

Comparing the minimum detection value of surface water in China and Japan, most indicators of Japan are more stringent than China. In some indicators, Japan implements “zero tolerance”, as shown in Table 4-2.

(iii) Marine environmental standards

In terms of the implementation of marine environmental standards, Japan also has a stricter indicators system than China, as shown in Table 4-3.

(3) The revision of standards in Japan is a routine work.

Japan keep attention on the quantity and value limits of environmental standard indicators, according to the changes in environmental conditions, Japan timely adjust the indicators and control values of water environment quality.

EQSSW of China was published in 1983, first revised in 1988, second revised in 1999, and latest revision was in 2002, it had not been revised for 17 years. SWQS had not been revised since issued in 1997, did not update for 22 years. Meanwhile, the situation of China's surface and sea water environment had changed, the corresponding evaluation criteria should be adjusted in time.

(4) Strictly implementation of standards is more important than publishing standards

Japan's marine environmental monitoring system is more complete by implementation of standards. According to implement situation of marine environmental monitoring in Japan, the structure and contents of marine environmental quality standard mainly includes: monitoring items, the standard value limit of selected items, analytical methods, monitoring methods, evaluation methods and characterization methods. This system constantly adjusted according to the needs of society and technological development. The different monitoring requirements, monitoring means, monitoring frequency and efforts level to control, reflect the need to take preventive measures to the strict control of the monitoring and management of pollutants

Japan had issued many relevant technical methods and monitoring manuals by the MoE. The key monitoring contents include six aspects: land-based pollution, ocean dumping, pollution caused by ships, pollution caused by development of submarine oil and gas fields, and pollution caused by development of deep-sea mineral resources.

Since the monitoring of sea water quality in China is carried out by multiple departments, to make monitoring data more comprehensive and scientifically that reflect sea water quality, the different standards to be referenced by various departments need to be coordinated in the setting and interconnection of indicators. China can keep improving a more complete, scientific and effective marine environmental monitoring mechanism with reference to Japan's successful experience in implementing marine environmental standards, establish scientific seawater quality assessment standards and methodologies.

4.5 Participation in marine environmental management

4.5.1 Japanese public supervision on MEP

According to the BEL of Japan, the environmental benchmark is a standard that is expected to be maintained in terms of protecting people's health and living environment. It is clear that the government must determine the level of control over the atmosphere, water, soil and noise, these goals are the basis for the government to carry out environmental protection work. The environmental benchmark means the nation hope to maintain a good environment. It is not the minimum to maintain human health, and it is a goal that people hope to actively maintain and strive to ensure. Environmental benchmarks have different requirements for different regions, or areas that are not currently polluted, environmental benchmarks that do not worsen, the status should be developed and hoped to be maintained. In addition, environmental benchmarks are based on current scientific knowledge, so it is necessary to conduct reasonable scientific judgments and revisions on a new basis by continuously collecting new scientific knowledge.

Japan pay attention to the specific actions of non-governmental organizations and enterprises to promote the governance of MEP problems. Under the guidance of government, Japanese industry companies, scholars and the public, all join local and social environmental protection works from their perspectives, and promote the implementation of laws and standards, including the marine environment. This is the important motivation of continuous improvement of the Japanese marine environment.

4.5.2 Chinese public participation in marine environmental management

China's marine environment management involves multiple departments. Although some regulations, policies and standards for marine environmental management had been introduced, but more stringent mechanisms need to be established for strict implementation, especially for guiding enterprises and NGOs to participate in the marine environment.

In China, economic development has the priority compared with environment protection, environmental protection is taken as a priority by central government, but not a priority by local government. Economic development has been the top one objective at provincial and prefectural level. As a result, environmental policy is not implemented stably, and the requirement of environment protection relaxed when economic development slowdown in recent years.

Chinese citizens had paid more attentions on air pollution, and pushed the government to take more efficient measures successfully, but less concerns on marine environment protection.

Chinese government has taken very strict measurement to control air pollution, the national and local government have their specific responsibilities for policy implementation, and provided detailed standards for industries to meet. As a result of strict "Environment Storm" that environment standard was taken strictly in some areas, and the factory that not meet with the standard was shut down. The enterprises that benefit from the "Environment Storm" for getting a bigger market support the policy while those shutdown enterprises against. Marine environment protection did not get enough attention compared with air pollution in China.

4.6 Summary

Comparative study on MEP between China and Japan implied that, Japan has a relatively strong national-level coordination mechanism on MEP, which can promote the policies, regulations and standards to be implemented well. On the other hand, China is lack of integration and coordination when facing the MEP problems, and China can do better facing MEP from Japan's lessons and experiences.

There are many departments designing marine environment in China, especially in the monitoring and management of marine environment, which belong to different departments, so, China is lack of synthesis coordination of measures focus MEP, and the coordination mechanism at the national level needs to be established. From Japan's experience, it is important to coordinate the related government branches facing MEP.

At the same time, China need make efforts to strengthen the law and standards enforcement inspectors, and gradually solve the general problems of non-compliance with laws and lax enforcement, encourage industry, scholars and the public to pay attention to and participate in the response to MEP, so as to realize the effectiveness and sustainable development of the management of marine ecological environment.

China also need call for international co-action, strengthen international co-action, deepening policy dialogues and practical cooperation, promote marine science and management practices sharing, collaboratively addressing challenges facing MEP, specially strengthen the cooperation with japan.

Table 4-1 Comparison of surface water quality standard between China & Japan

	China	Class I	Class II	Class III	Class IV	Class V
	Japan	Class AA	Class A	Class B		-
pH (no unit)	China		6-9			
	Japan	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.5	-
Dissolved oxygen (mg/L)	China	≥7.5	≥6	≥5	≥3	≥2
	Japan	≥7.5	≥7.5	≥5	≥2	-
COD (mg/L)	China	≤15	≤15	≤20	≤30	≤40
	Japan	≤1	≤3	≤5	≤8	-

Source: MEE of China, 2002, Environmental quality standard for surface water.
MoE of Japan, 2009, Environmental quality standards for water pollution.

Table 4-2 Comparison of limit values in surface water quality between China & Japan

mg/L	China	Japan
Zinc	≤0.05	≤0.01
Fluoride	≤1.0	≤0.8
Selenium	≤0.01	≤0.01
Arsenic	≤0.05	≤0.01
Cadmium	≤0.001	≤0.01
Chromium (hexavalent)	≤0.01	≤0.05
Lead	≤0.01	≤0.01
Carbon tetrachloride	≤0.002	≤0.002
Dichloromethane	≤0.02	≤0.02
Petroleum	≤0.05	Not detected
Cyanide	≤0.005	Not detected

Source: MEE of China, 2002, Environmental quality standard for surface water
MoE of Japan, 2009, Environmental quality standards for water pollution

Table 4-3 Comparison of sea water environmental quality standard between China & Japan

mg/L		Class I	Class II	Class III	Class IV
pH	China	7.8-8.5		6.8-8.8	
	Japan	7.0-8.3 (Class A&B)		7.8-8.3 (C)	
COD	China	≤2	≤3	≤4	≤5
	Japan	≤2 (A)	≤3 (B)	≤8 (C)	
DO	China	≤6	≤5	≤4	≤3
	Japan	≤7.5 (A)	≤5 (B)	≤2 (C)	-
Total coliform	China	≤10000			-
	Japan	≤10000(A)	-	-	-
Zinc	China	≤0.020	≤0.050	≤0.10	≤0.50
	Japan	≤0.01 Special Class A	≤0.02 Class A		

Source: MEE of China, 1997. Sea water quality standard of China (GB 3097-1997)
MoE of Japan, 2009. Environmental quality standards for water pollution.

Chapter 5 Conclusion

5.1 Research findings

The research found that, with the economy development in of China, the MEP problem is facing serious challenges, which has not been paid enough attention by Chinese government and the public. The study analyzed the latest situation of MEP in China, and claimed that the land-based pollutants are the main sources of MEP in China. Thus, the environmental pollution problems for sea and land need to be considered as a whole system to deal with.

According to two main standards for evaluating the quality of surface water and seawater in China, the research found that, although the overall situation of MEP in China became better during these years, however, the main pollution indicators of the seawater quality, such as inorganic nitrogen, active phosphate, chemical oxygen demand (COD) and petroleum pollution, etc. did not meet the standard. The MEP mainly comes from the flowing rivers and land sewage outlets into the sea, the land pollution source control is very important to MEP.

Results for MEP of 4 main sea areas in China (the Bohai Sea, Yellow Sea, East China Sea and South China Sea) proved that each area has different characteristics in MEP, this is correlated the situation of economy in some typical coastal provinces and cities in China.

Case study of Shandong provided a further understanding of MEP in China, it implied that, economic structure, coal-dominated energy structure had brought about much land-based pollution emissions and various challenges to the MEP of Shandong, such as large areas of green tides and red tides, greatly affecting the swimming beaches during the tourist seasons. Qualitative research based on in-depth interview analyzed the complex views of different stakeholders, found that lack of public participation is a key issue in the understanding and actions facing MEP.

Comparative study between Japan and China implied that, in order to effectively deal with the problem of marine pollution, Japan had comprehensively strengthened the marine space management mechanism at the national level, and had strictly implemented the establishment of a relatively complete marine environmental policy regulations and standards system.

China and Japan have differences in management mechanisms and implementation processes facing MEP. In Japan, the MEP related policy not only implement under central government's powerful role, but also implement by local governments at all levels and involved actively by private institutions and public participations; Japan's marine environmental policy has a continuous implementation after their formulation. Laws and standards of Japan are more comprehensive and revised more frequently than China.

Japan had already adopted the principle of “environmental priority” in dealing with the relationship between economic development and marine environmental management, rather than the understanding and treatment mechanism of “coordinated development of environment and economy” that China currently adopts.

China can benefit a lot from Japan’s lessons and experiences in MEP. Through the comparison on the government's marine management mechanisms and the implementation of marine environment laws, plans, related standards, and public participation with respect to MEP, the research found that Japan has a relatively strong national-level coordination mechanism on MEP, which can promote the policies, regulations and standards to be implemented well, while China is lack of integration and coordination when facing the MEP problems.

Taking Japan as a reference, policy recommendations for China's MEP are expected to have potentially practical values for China to cope with the challenges of MEP problems.

5.2 Policy recommendations

Refer the experience of Japan, some suggestions can be recommended to policy makers coping with the challenges of MEP in China.

Facing the serious challenges of MEP, main policy suggestions to China includes: economic structure adjustment, change the energy consumption structure, especially develop coastal tourism and other marine tertiary industry; strictly implementation of legal regulations and standards; monitoring capacities building on MEP; encourage public participation; promote environmental education and awareness; integration of marine environment protection with economic decision, etc.

5.2.1 China's MEP needs to wake up enough attention

In the process of China's rapid economic development, various environmental problems have become more prominent. In recent years, especially the “smog” disaster caused by air pollution problems in northern China has become more prominent. In fact, China still faces more difficulties in environmental pollution, such as water, soils which had been monitored less and neglected. For MEP, due to various reasons such as understanding, management mechanism, technology, and investment, although it is very serious, but had not got sufficient attention, and had been paid corresponding measures in time. The latest situation of MEP in China had not got scientific research and fundamentally governed, some areas are still in the process of increasing pollution, this problem should be highly valued by China and the international community, and the corresponding reactions facing China’s MEP should be taken as soon as possible.

5.2.2 Strengthen monitoring system of MEP

Detection and comprehensive treatment of MEP control is very important, he pollution control of key sea areas should be implemented, especially monitor and evaluate key pollution source emissions timely. Strictly control marine aquaculture pollution, strengthen pollution control of river estuaries, key bays, and coastal sea waters; establish a marine environmental emergency monitoring and emergency response system to effectively prevent MEP disasters, such as red tides and green tide; Closely monitor the pollution of marine vessels and oil spills, and strive to ensure the emissions from land-source sewage outlets, offshore oil platforms and other artificial facilities to achieve corresponding standards.

Explore integrated marine environmental monitoring systems across multiple sectors to provide a scientific, continuous data system for marine environmental monitoring.

At present, the monitoring of China's MEP comes from several departments, including the following departments:

- Environmental monitoring and data release for all jurisdictions, this is organized and implemented by the State Oceanic Administration (SOA) of China.
- The environmental quality of the coastal waters, the ecological environment of the important estuary and the status of land-contaminants entering the sea are monitored by the Ministry of Environmental and Ecology (MEE), which is supported by the “National Nearshore Water Environment Monitoring Network”.
- The environmental status of marine fishery waters is monitored by the National Fisheries Eco-environment Monitoring Network, which is belongs to the Ministry of Agriculture and Rural Affairs (MARA) in China; the fishery water pollution accidents are issued by the Fisheries Bureau of MARA.
- Ship pollution accidents are released by the Maritime Safety Administration of the Ministry of Transportation in China.

Monitoring data comes from different sectors, the integration and continuity of monitoring indicators and monitored results needs to be improved.

5.2.3 Management of land pollution sources

Implement a total amount control plan for major pollutants, such as nitrogen, phosphorus and petroleum hydrocarbons. Increase the supervision of sewage companies and strictly implement the total amount control and discharge permit system. Enterprises with seriously polluted and worse technology, which can’t meet the environmental emissions standards should be eliminated according to laws. Reduce industries with high energy consumption and high pollution emissions. Accelerate the construction of desulfurization and denitrification facilities in coal-fired power plants, steel and other industries, and significantly reduce sulfur dioxide and nitrogen oxide emissions. Strengthen the control of industrial particulate matter and dust pollution, and pay much attention on the safe disposal of industrial hazardous solid waste.

The control of agricultural pollution is mainly to increase the prevention and control of soil pollution, comprehensively promote clean cultivation, and strengthen pollution prevention and control of livestock and poultry breeding.

The pollution control of urban and rural residents' living is mainly to improve the comprehensive disposal and utilization level of domestic waste, accelerate the construction of centralized sewage treatment facilities in coastal cities, improve the sewage treatment infrastructure, and speed up the ratio that can reach the standard after sewage treatment. Strengthen the pollution control of rivers into the sea, strictly discharge of land-based sewage treatment by standards.

5.2.4 Simultaneous management of marine and land environment

Manage and control pollution with marine and land together, consider rivers and ocean as one linked ecosystem to cope with marine environmental issues, implement strict environmental protection standards and total pollutant discharge.

A good choice in managing marine environment is to set up and perfect the protection zones both in coastal and distant sea areas, according to the distance from the land, the sea areas can be divided different marine environmental protection zones, according to the carrying capacity of ecological environment in different sea areas, rationally arrange development activities.

In the coastal protection zones, where are belt-shaped areas extending from the coastline to the land, it is a space that have both marine and terrestrial environment, and also it was with the characteristics of developed marine industry (such as coastal tourism and fishery economy) and dense population. In this area, protect the coastline, tidal flats islands, wetland and bays are important.

From the coastal areas to outer near sea areas, where have abundant marine fishery, energy, and mineral resources. In this sea area, In order to effectively protect marine environment, the fishing season must be strictly enforced and prohibited, prevent marine oil and gas mining, ship navigation and dumping wastes, which can cause MEP problems.

From the near sea areas to far sea areas, it is necessary to comply with the international obligations and duties of protecting the marine environment, and strengthen international cooperation for maintaining the balance of the marine ecosystem.

5.2.5 Strengthen international cooperation on marine environment

The problem of MEP is one of the major environmental challenges facing all mankind today. As a connected water system, the ocean is characterized by its fluidity. The world's oceans are connected to each other. The movement of sea water, the migration of marine life, and the movement of marine pollutants under the influence of wind, waves and currents migrate from one sea area to another sea area, this process is not subject to the boundaries of national boundaries and territorial waters. Therefore, to solve the international problem of MEP, it is far from enough to rely solely on the unilateral measures of individual countries. It is necessary for all countries to make joint efforts to carry out international cooperation.

Both China and Japan are facing the similar challenge of MEP, it is not only necessary to conduct comparative study on the marine environment, but also to carry out cooperation. This will not only benefit the people of China and Japan, but also play a positive role in the response of all human beings to the challenges of MEP. The further study is contribute to the policy suggestions and actions for marine environment protection both in China and Japan.

5.3 Future research

The study found that the relationship between economic growth and MEP is really complex, whether from a quantitative or qualitative analysis perspective. Different provinces in China's coastal areas are in different stages of economic development. To analyze the relationship between economic growth and MEP, it is important to select the proper region as case study, indicators and models, these issues need to be further studied. More research findings can support the new policy recommendations for China's marine environmental management.

The MEP cover a huge research topics, involving many environmental pollution indicators. The understanding and analysis of MEP based on environmental pollution data are still under exploration. It is important to public the primary monitoring data, not only necessary for scientific research, but also helpful for data evaluation. The researches on MEP need to be explored further using data from both marine and land-based pollution.

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Appendix 1

Basic factors values limit of China's surface water environmental quality standard
(GB 3838-2002) unit: mg/L

No.	Factors	Class I	Class II	Class III	Class IV	Class V
1	Temperature(°C)	The artificially caused changes in water temperature should be limited to: weekly average maximum increase ≤1°C; weekly average maximum temperature drop≤2°C				
2	pH:(no unit)		6-9			
3	Dissolved oxygen	≥7.5	≥6	≥5	≥3	≥2
4	Permanganate index	≤2	≤4	≤6	≤10	≤15
5	COD	≤15	≤15	≤20	≤30	≤40
6	BOD_5	≤3	≤3	≤4	≤6	≤10
7	NH_3-N	≤0.15	≤0.5	≤1.0	≤1.5	≤2.0
8	Total phosphorus	≤0.02	≤0.1	≤0.2	≤0.3	≤0.4
9	Total nitrogen	≤0.2	≤0.5	≤1.0	≤1.5	≤2.0
10	Copper	≤0.01	≤1.0	≤1.0	≤1.0	≤1.0
11	Zinc	≤0.05	≤1.0	≤1.0	≤2.0	≤2.0
12	Fluoride	≤1.0	≤1.0	≤1.0	≤1.5	≤1.5
13	Selenium	≤0.01	≤0.01	≤0.01	≤0.02	≤0.02
14	Arsenic	≤0.05	≤0.05	≤0.05	≤0.1	≤0.1
15	Hg	≤0.00005	≤0.00005	≤0.0001	≤0.001	≤0.001
16	Cadmium	≤0.001	≤0.005	≤0.005	≤0.005	≤0.01
17	Chromium (hexavalent)	≤0.01	≤0.05	≤0.05	≤0.05	≤0.1
18	Lead	≤0.01	≤0.01	≤0.05	≤0.05	≤0.1
19	Cyanide	≤0.005	≤0.05	≤0.2	≤0.2	≤0.2
20	volatile phenols	≤0.002	≤0.002	≤0.005	≤0.01	≤0.1
21	Petroleum	≤0.05	≤0.05	≤0.05	≤0.5	≤1.0
22	anionic surfactants	≤0.2	≤0.2	≤0.2	≤0.3	≤0.3
23	Sulfides	≤0.05	≤0.1	≤0.2	≤0.5	≤1.0
24	Fecal coliforms (number/L)	≤200	≤2000	≤10000	≤20000	≤40000

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Appendix 2

Sea water quality standard of China's (GB 3097-1997) unit: mg/L

No.	Factors	Class I	Class II	Class III	Class IV
1	floating substance	Oil film, floating foam and other floating substances shall not appear on the sea surface.			No obvious oil film, floating foam and other floating substances on the sea surface
2	color &smell	sea water must not have any different color and smell			Sea water must not have unpleasant color, smell
3	suspended materials	artificial increase(AI) ≤10		AI≤100	AI≤150
4	total coliform (number/L)	10000；shellfish culture water for human consumption≤700			-
5	fecal coliforms (number/L)	2000； Shellfish culture water for human consumption≤140			-
6	pathogen	The water quality of shellfish culture for human consumption must not have pathogens			
7	temperature(°C)artificially caused sea temperature rises	in summer≤1°C, other seasons≤2°C		in summer≤4°C	
8	pH:(no unit)	7.8-8.5		6.8-8.8	
9	dissolved oxygen	≥6	≥5	≥4	≥3
10	COD	≤2	≤3	≤4	≤5
11	BOD_5	≤1	≤3	≤4	≤5
12	Inorganic nitrogen	≤0.20	≤0.30	≤0.40	≤0.50
13	Nonionic ammonia	≤0.020			
14	active phosphate	≤0.015	≤0.030		≤0.045
15	Hg	≤0.00005	≤0.0002		≤0.0005
16	cadmium	≤0.001	≤0.005	≤0.010	
17	lead	≤0.001	≤0.005	≤0.010	≤0.050
18	chromium (hexavalent)	≤0.005	≤0.010	≤0.020	≤0.050
19	total chromium	≤0.05	≤0.10	≤0.20	≤0.50
20	arsenic	≤0.020	≤0.030	≤0.050	
21	copper	≤0.005	≤0.010	≤0.050	
22	zinc	≤0.020	≤0.050	≤0.10	≤0.50
23	selenium	≤0.010	≤0.020		≤0.050
24	nickel	≤0.005	≤0.010	≤0.020	≤0.050

25	cyanide		≤0.005		≤0.10	≤0.20
26	sulfide		≤0.02	≤0.05	≤0.10	≤0.25
27	volatile phenol		≤0.005		≤0.010	≤0.050
28	petroleum		≤0.05		≤0.30	≤0.50
29	hexachlorocyclohexane (BHC)		≤0.001	≤0.002	≤0.003	≤0.005
30	dichlorodiphenyltrichloroethane (DDT)		≤0.00005	≤0.0001		
31	malathion		≤0.0005	≤0.001		
32	methyl parathion		≤0.0005	≤0.001		
33	benzoapyrene (ug/L)		≤0.0025			
34	anionic surfactant,		0.03	0.10		
35	Radio-nuclide (Bq/L)	^{60}Co	0.03			
		^{90}Sr	4			
		^{106}Rn	0.2			
		^{134}Cs	0.6			
		^{137}Cs	0.7			

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