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Executive summary

The ocean is vital to all life on Earth, providing many provisioning, regulating and supporting services. If human activities are not carefully managed to ensure that they do not alter ecosystem structure and function, they may result in damage to the marine environment and reduction or loss of crucial ecosystem services. Growing populations and economies and the agricultural and industrial requirements for feeding, clothing and housing the world's population are seriously degrading parts of the marine environment, especially near the coast.

The lack of sewage and wastewater treatment (especially for the removal of nutrients in some areas) and the release of pollutants from industrial, shipping and agricultural activities are major threats to the ocean, particularly in terms of food security, safety and maintenance of marine biodiversity. The ocean also suffers from the sewage, garbage, spilled oil and industrial waste which we collectively allow to go into the ocean every day. Beyond the obvious direct link to marine water quality, the volume of pollutants discharged into the sea has a direct connection to huge economic costs tied to marine fisheries, marine tourism, and human health and safety. Marine pollution also causes environmental degradation, the decline in biological diversity, and the loss of ecosystem services, each of which may be difficult to account for in monetary terms but is significant nonetheless.

Often, while production and emission to a large degree is land-based, the marine environment is in fact the end recipient. In addition to the well-known eutrophication effects from terrestrial nutrient input, the globally growing plastic pollution challenge is another prime example of such interactions. The use of the best practicable means to limit the creation of waste, discharges and emissions can help control these problems. However, continued growth in industrial production means that, even with this help, discharges and emissions will increase the inputs of heavy metals and other hazardous substances into the ocean. The only way to avoid this result is for innovations in cleaner production methods and means of reducing discharges and emissions to keep pace with the growth in production. This is particularly the case in areas of rapid industrial growth.

In the 40 years following the Chinese economic reform and opening policy, China has formed a coastal ribbon of high economic development, which has brought with it population density and urbanization. Coastal and marine ecosystems are subject to tremendous ecological damage and land-based pollution pressures while supporting coastal economic development. The ability to sustain development has declined significantly. More than 70% of nutrients discharged into the sea are from land-based origins, and these and other sources of pollution being leached into the marine environment have led directly to a decline in marine water, sediment and biological quality. Changes in the nutrients in coastal water were closely related to China's economy growth rate, development pattern, population growth, as well as environmental protection policies and measures. The nutrient inputted to the sea increased rapidly during the end of the 1980s to the beginning of the 21st century, with a high rate of growth in real GDP. In recent 7 years, the increasing trend in nutrient inputs to the sea has been shifted, a steadily decreasing trend has been observed, and the status of coastal areas on eutrophication has improved over the last five years. Other than the nutrients, emerging contaminants and emerging issues have caused great concerns in China. The abundances of floating litter and microplastics in China's coast were the same order of magnitude as those reported in samples from the North Atlantic coast and South Pacific subtropical coast. Relatively high abundances of microplastics in water and sediment were recorded in the Estuaries and fishing harbors. Emerging contaminants, SCCPs, PBDEs, OCPs and antibiotics have been ubiquitous in China's coast, especially in the Bohai Sea. Beyond the obvious direct link to marine water quality, the volume of pollutants discharged into the sea has a direct connection to huge economic costs tied to marine fisheries, marine tourism, and human health and safety. Marine pollution also causes environmental degradation, the decline in biological diversity, and the loss of ecosystem services, each of which may be difficult to account for in monetary terms but is significant nonetheless.

Several challenges are facing global oceans: inadequate knowledge; ineffective sector/cross-sector policies, cooperation and governance systems; inadequate solutions and incentives to enable and encourage resource efficiency and circular economy approaches; and insufficient public and private financing. Multiple global legal and institutional frameworks for ocean governance exist but is fragmented, and mostly sector-specific. To achieve integrated ocean governance, some concepts such as Blue Economy, Circular Economy, and Source to Sea Approach, are emerging and applied by countries. Actions have been taken at the global level to target marine pollution such as nutrients, wastewater, marine litter and antibiotics. Marine pollution and Ocean governance are now high on the agenda at global, regional and national levels. Although laws and policies have been much improved in the last ten years, there are still some existing gaps which prohibit China from fully implementing its obligations in the international conventions and protect its marine environment and resources. The gaps exist in Lack an integrated ecosystem-based view, lack of laws in protection of resources and ecosystem, lack of detailed implementation rules and lack of a cross-sector implementation mechanism.

Recently, China has made full use of the substantial foundation accumulated over the past 40 years of economic reform, and step up efforts to promote ecological civilization construction. Pollution control is one the three tough battles which Chinese government must win. At present, the China's environmental quality has been going to improve. There is tremendous opportunity for China to promote the common welfare of nations by pursuing a path of harmony between people and the ocean, promoting conservation and green development of the oceans, enhancing ocean-based prosperity, helping to achieve maritime security, promoting innovation and contributing to collaborative governance. That is the same case for marine pollution governance. China's ecological civilization construction is a useful exploration and practice of the sustainable development, providing an economic reference for other countries to deal with similar economic, environmental and social challenges.

I. Establishing a holistic mechanism of land-sea coordination in joint marine pollution prevention and control

Significantly enhance the land-sea ecological environment monitoring unity. In accordance with the principle of land-sea coordination and the unified plans, optimize the construction of a fully covered and refined marine ecological environment monitoring network, strengthen gridded and real-time monitoring, and develop the online monitoring for the primary rivers and outlets discharging and atmospheric deposition of pollutants into the sea. Establish a baseline survey/census system for marine pollution.

Enhance management and prevent land-based pollution from the agricultural, pharmaceutical sectors. Full consideration should be given to improving overall agricultural production capacity and to preventing and controlling rural pollution. Environmental protection facilities, such as those for handling rural wastewater and refuse, should be developed. A variety of assistive measures should be adopted to foster and develop market entities for the control of all types of agricultural pollution from non-point sources and for the handling of rural wastewater and refuse. Green production way in agriculture should be pursed to promote making full use of agricultural wastes. A green finance system is encouraged to support the pilot of disposal and harmless treatment of livestock and poultry breeding. Comprehensive utilization of livestock and poultry manure might be gradually achieved on the spot. The management of antibacterial drugs used for human and animals should be strengthened. Proper procedures should be introduced to restrict the use of chemicals such as antibiotics in accordance with the law.

Further improve China's marine environmental quality target system. China's marine environmental quality target system is mainly based on water quality targets, which are often expressed by the under-criteria rate of marine functional zoning or clean water (below the criteria of grade I, II). Suggest to further enrich the content of China's marine environmental quality target system, in addition to the water quality target, the spatial and temporal distribution characteristics of marine ecosystems need to be combined, further increase marine ecological protection target, such as the biodiversity, habitat suitability, ecosystem structure and function, etc., lay the foundation and direction for the marine ecological protection work. Strengthen the connection of sorting, indices selecting, and valuing of water quality standards between surface water and seawater, and introduce new indices such as total phosphorus, total nitrogen, and emerging pollutants. Advance seawater quality standards revision. Take a holistic approach for emissions control and water quality target management in the river basins and offshore areas.

Construct an integrated governance mechanism for the River Chief and Bay (Beach) Chief systems. In accordance with the holistic approach to conserving our mountains, rivers, forests, farmlands, lakes, and grasslands, strengthen coordination of the comprehensive management of rivers discharging into sea, bay and estuarine. Establish a joint-action mechanism between the River Chief System and Bay Chief System, set a regular consultation mechanism and emergency response mechanism, and enhance the capability of pollution prevention and control in a holistic approach for land and sea.

II. Strength lifecycle management for plastics, and formulates a national action plan for marine debris pollution prevention and control

Strengthen the source control of plastics debris. Explore the waste reduction and harmless management pattern in line with national conditions, and effectively prevent the entry into marine environment of microplastics and plastic waste resulting from the manufacturing production and individual consumption process, severe weather events and natural disasters in coastal regions. Strengthen the management of plastic nurdle, and put on file and supervise of the process of “resin nurdles - plastic products – usage and circulating of commodity”. Encourage extended producer responsibility (EPR) and related mechanisms. Promote EPR mechanisms to involve producers, importers and retailers in the establishment of resource-efficient product value chains from the design to the end-of-life treatment and in financing waste collection and treatment. Forbid to produce and sell personal care products containing plastic micro-beads. Introduce technologies in washing machines to better capture fibres from wash-loads in both domestic and commercial/industrial uses.

Support integrated sustainable waste management. Improve and developing national waste regulatory frameworks, including legal framework for EPR, and taking care for enforcement and governance. Support capacity development and infrastructure investments for improved waste management systems in cities and rural areas through existing instruments, and promote access to regular waste collection services and facilitate investments in waste management infrastructure in order to prevent plastic waste leakage into the sea. Establish sufficient waste reception facilities at harbors in coastal cities in order to allow ships to dispose of their waste in an environmentally sound manner.

Formulate a national action plan for marine debris pollution prevention and control.

Promote the establishment of sound national regulatory frameworks on waste management. Construct an integrated coordination mechanism for marine debris prevention and control across sectors, regions and river basins. Encourage green development, speed up the research and application of innovative approach for substitute for plastic products and waste treatment, and urge the manufacturing and use of degradable plastic products and substitutes for plastic. Strengthen researches on sources, transport and fate of microplastics as well as the impact on marine ecological environment, and improve the scientific understanding of microplastics. Call on all relevant stakeholders to engage and encourage social organizations, communities and the public to reduce plastic waste generation, hold clean-up activities, significantly reduce the unnecessary use of single-use plastics, and live green-consumption lifestyle, with the aim to prevent and significantly reduce marine microplastic pollution.

III. Develop a market system which allows economic levers to play a greater role in marine environmental governance and ecological conservation

Accelerate industrial innovative and green development and transformation in coastal areas. Promote industrial upgrading toward to emerging industries and modern service industries. Strengthen the construction of industrial zones, promote circular economy and green production, build ecological industrial zones, and enhance the integrated and recycling utilization of resources. Set the binding requirements including industrial structure and layout, resource and environmental capacity loads, and ecological red lines. Strengthen the management of project approval, enhance the market entry, compel industrial transformation and upgrading, and progressively fall into disuse lagged behind production capacity.

Improve the system for compensating marine ecology conservation efforts. Persist to the principle of "who benefits, who compensates", comprehensively use fiscal, taxation and market measures, adopt the form of incentive instead of subsidies, and establish a compensation mechanism for marine ecological conservation.

Strictly implement compensation systems for ecological and environmental damage. Tighten manufacturers' legal responsibilities for environmental protection, and significantly increase the cost of illegal activities. Improve legal provisions concerning marine environmental damage compensation, methods for appraising damage, and mechanisms for enforcing compensation. In accordance with the law, mete out penalties to those who violate environmental laws and regulations, determine compensation for ecological and environmental damage by the extent of damage and other factors, and pursue criminal liability when violations result in serious adverse consequences.

Establish a diversified funding mechanism. Integrate various types of marine environmental protection funds by central budget, increase financial support, and keep supporting the rural environmental governance and Blue Bay restoration actions. Bring into full play the initiative of local budget, enhance local financial support, make full use of market investment and financing mechanisms, and encourage and attract private, social, venture capital and other funds to gather in the area of marine environment protection.

IV. Strengthen protection and remediation of coastal wetlands, and restore the ecological functions of wetlands including water purification

Improve coastal wetland grading management system. Establish important coastal wetlands grading management systems at national and local levels, release in batches the national important coastal wetlands list, and identify the control proportion target of coastal wetlands at local level. Innovate the protection pattern, and establish the coastal wetland pilot national park.

Establish degraded coastal wetlands restoration system. In accordance with the natural attributes of marine ecosystems and the characteristics of coastal biota, carry out the coastal wetland restoration. Implement the restoration projects, including restoring the coastal aquaculture farms back to wetlands, culturing densely vegetation, conserving habitat, improve the community structure of wetland vegetation, and raise the biodiversity of wetland habitats. Expand the coastal wetland area and recover the ecological services of wetland, such as water purification, carbon sequestration. By 2020, the restored area of coastal wetland will be more than 20,000 hectares.

V. Strengthen cooperation and exchanges, and jointly address global marine pollution

Strengthen research on emerging marine environmental issues of global concerns. Conduct survey and research on ocean acidification, plastics and microplastics, oxygen deficiency in hotspot areas, and comprehensively analyze the emerging marine environment issues of global concerns, particularly in the high seas and Polar Regions. Deeply participate in the designation of high seas protected areas, environmental impacts assessment of seabed development activities, and research on marine environmental protection in Polar Regions, and play our part in global marine environmental governance.

Establish Maritime Community with a Shared Future to jointly address marine pollution. With the aid of the 21st Century Maritime Silk Road, carry out pragmatic and efficient cooperation and exchange under the framework of the Asian Infrastructure Investment Bank, China-Pacific Island Economic Development Cooperation Forum, China-ASEAN Maritime Cooperation, and Global Blue Economy Partnership Forum etc. Strengthen research on marine environmental issues of global concerns, build a broad blue partnership, jointly improve the ability to address and control marine pollution. Establish China-ASEAN Marine Environmental Protection Cooperation Mechanism, and promote international cooperation. Enhance capacity on pollution monitoring and governance through sharing knowledge making best use of other relevant efforts in the region such as PEMSEA, APEC, NOWPAP and COBSEA, GPML, GPNM, GWI and work together to build a community of shared future for mankind.

1. Introduction

Marine pollution is a problem and challenge all countries face, and a priority for China, a series of measures have been taken to tackle marine pollution: according to the new cabinet restructuring plan, marine pollution, previously overseen by the State Oceanic Administration is now under the mandate of the Ministry of Ecology and Environment, and in November 2018, China and Canada released the Joint Statement between Canada and China on Marine Litter and Plastics, China is also taking active parts in global and regional efforts, such as the global negotiation process on marine litter, the Coordinating Body on the Seas of East Asia (COBSEA) and the Northwest Pacific Action Plan (NOWPAP).

Chinese President XI Jinping reiterated the importance of marine environment. During his visit to Africa in July 2018, he pointed out that the blue economy is incorporated into African Agenda 2063 for socioeconomic transformation. China has taken the lead in pushing for marine-friendly cooperation and can offer Africa the support it needs to exploit its blue world. In a signed article in a Portuguese newspaper, published during his state visit to the country, President XI Jinping mentioned that the two countries need to lead the way in growing the blue economy by promoting maritime cooperation. Portugal, known for its tradition of maritime expedition, has a time-honoured maritime culture and rich experience in the exploitation of marine resources. The Blue Partnership between China and other coastal states needs to be strengthened to facilitate cooperation in marine research, ocean development and protection, port logistics and other areas, and grow blue economy together to better harness the vast ocean to the benefit of future generations.

Oceans flow over nearly three-quarters of our planet and hold 97 % of the planet's water. The ocean is vital to all life on Earth, providing many provisioning, regulating and supporting services. They provide living and non-living resources, facilitate shipping and other maritime uses, and play a key role in the global climate and weather system. Oceans and Coasts are the very basis of much of the world's economy. 350 million jobs around the world are linked to the oceans[1].

The marine environment, its resources and its biodiversity are under increasing threat from sewage, garbage, spilled oil and industrial waste which we collectively allow into the ocean every day. Pollution from both maritime and terrestrial sources has therefore drawn growing attention, it is roughly estimated that 80 % of marine plastic debris comes from land, though there is not sufficient evidence to corroborate that, what can be said with certainty is there are very significant regional differences in the degree to which waste is subject to collection and management, either as wastewater or solid waste (UNEP, 2016). A study estimated the total number of floating macro and microplastic pieces in the open ocean to be 5.25 trillion, weighing 269,000 tonnes (UNEP, 2016). 8,300 million metric tons (Mt) of virgin plastics have been produced to date; 6,300 Mt of plastic waste has been generated as of 2015; of this waste, 9% has been recycled, 12% incinerated, and 79% has accumulated in landfills or the natural environment; 12,000 Mt of plastic waste will be in landfills or in the natural environment by 2050 under current production and waste management trends (Geyer et al, 2017). Globally, over 80% of all wastewater (over 95% in some developing countries) is discharged without treatment (WWAP, 2017). Long-term solutions including improved governance at all levels as well as behavioural and system changes will support the transition to a circular economy and sustained Oceans.

[1] Why does addressing land-based pollution matter? UN Environment website, https://www.unenvironment.org/explore-topics/oceans-seas/what-we-do/addressing-land-based-pollution/why-does-addressing-land

This report aims to review the current statuses and policies on marine pollution in China, take stock of ongoing global and national ocean initiatives, and then recommend how China can contribute to these efforts, and how CCICED and China could work further with regard to marine pollution, in short- and long-term perspectives as well as at national, regional and global levels. The report will first look at marine pollution in China, specifically on nutrients, marine litter, short-chain chlorinated paraffins (SCCPs), polybrominated diphenyl ethers (PBDEs), Organochlorine Pesticides (OCPs), Polychlorinated biphenyls (PCBs), Polycyclic aromatic hydrocarbons (PAHs) and antibiotics, identify status and sources of marine pollution in China, impact on the ecosystems, and existing coastal and ocean pollution policies, then it turns to a global view, and map ongoing international ocean governance structures, emerging concepts for marine pollution, and national measures. Recommendations are then provided at the end of the report.

2. Marine pollution in China

Driven by rapid exploitation and utilization process, Chinese ecosystem has undergone profound changes over the past four decades. Currently, China has entered a new era. We should recognize that the Marine Eco-Civilization construction puts forward new requirements for marine environment protection, and therefore marine environment status and the source of marine pollution along Chinese coast should be identified.

According to the "China Marine Environmental Quality Bulletin" annually issued by the former State Oceanic Administration over the years, due to the excessive input of land-based nutrients into the sea, the main pollutants are inorganic nitrogen, active phosphate, etc., and these resulted in eutrophication in China's coastal waters. The adverse impacts of emerging pollutants (such as marine debris and microplastics, antibiotics, short-chain chlorinated paraffins, new flame retardants, etc.) are gradually arising in China's coastal waters. Thus, the aim of this section is to comprehensively overview of the current status of major pollutants, including nutrients, marine debris and microplastics, short-chain chlorinated paraffins (SCCPs), polybrominated diphenyl ethers (PBDEs), organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), antibiotics.

2.1 *Nutrients and Eutrophication*

Chinese strategic objective on eutrophication is to maintain a healthy marine environment. Eutrophication is the result of excessive enrichment of water by nutrients (Strokal et al., 2014). Chinese coastal waters receive increasing amount of nutrients from rivers due to rapid economic development and population growth. Between 2001 and 2017 (SOA, 2018), the maximum of sea areas that do not meet the clean water standard is 177 720 km^2 in 2010. The mean of sea areas with water quality worse than the SQSC (Seawater Quality Standard Category) IV were 36 102 km^2 (SOA, 2018). During period from 2012 to 2017, the sea areas with water quality meeting the SQSC I showed a significant increase in the Bohai Sea. DIN (Dissolved inorganic nitrogen) and DIP (Dissolved inorganic phosphate) are the major pollutants. In summer and winter of 2017, the sea areas with inorganic nitrogen concentrations SQSC IV were mainly located at the inshore areas of Liaodong Bay, Bohai Bay, Laizhou Bay, Jiangsu Coast, Yangtze River Estuary, Hangzhou Bay, Zhejiang Sea Coast, and Pearl River Estuary. The sea areas with DIP concentrations worse than the SQSC IV were mainly located at the inshore areas of Yangtze River Estuary, Hangzhou Bay, Zhejiang Coast, and Pearl River Estuary.

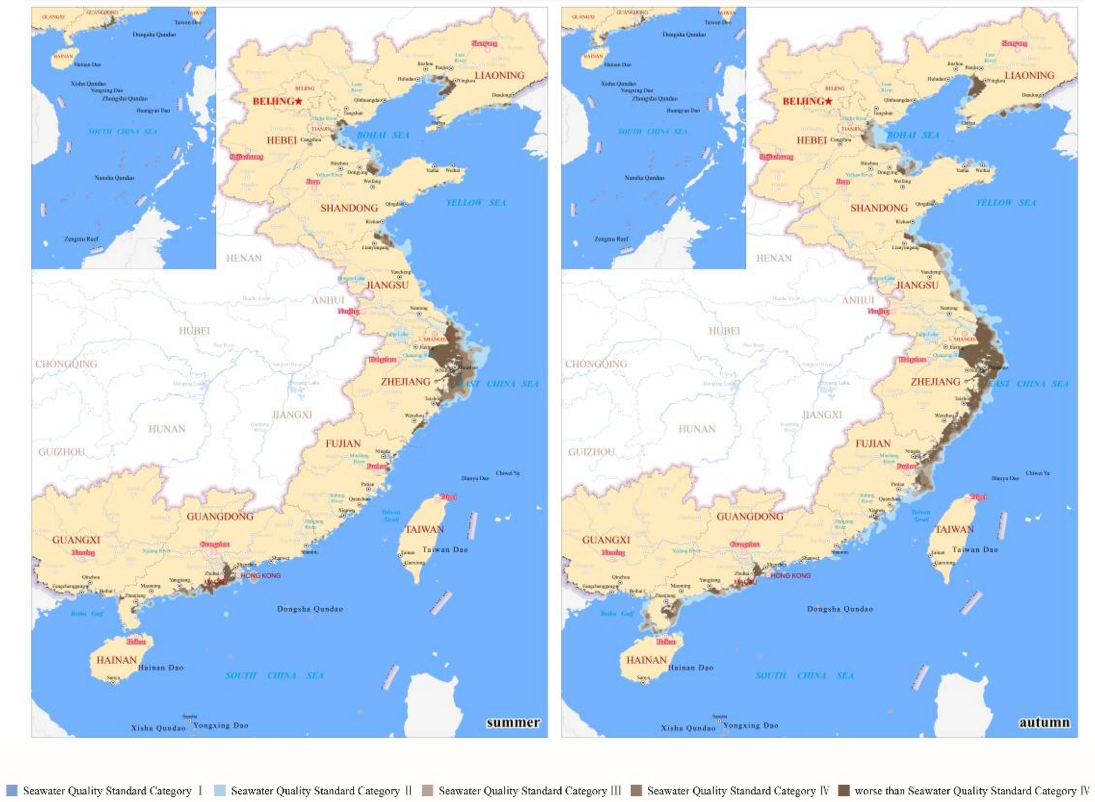


Figure 2. 1 Distribution of seawater quality categories of dissolved inorganic nitrogen (DIN) in the national jurisdictional sea area in the summer and autumn of 2017 (SOA, 2018)

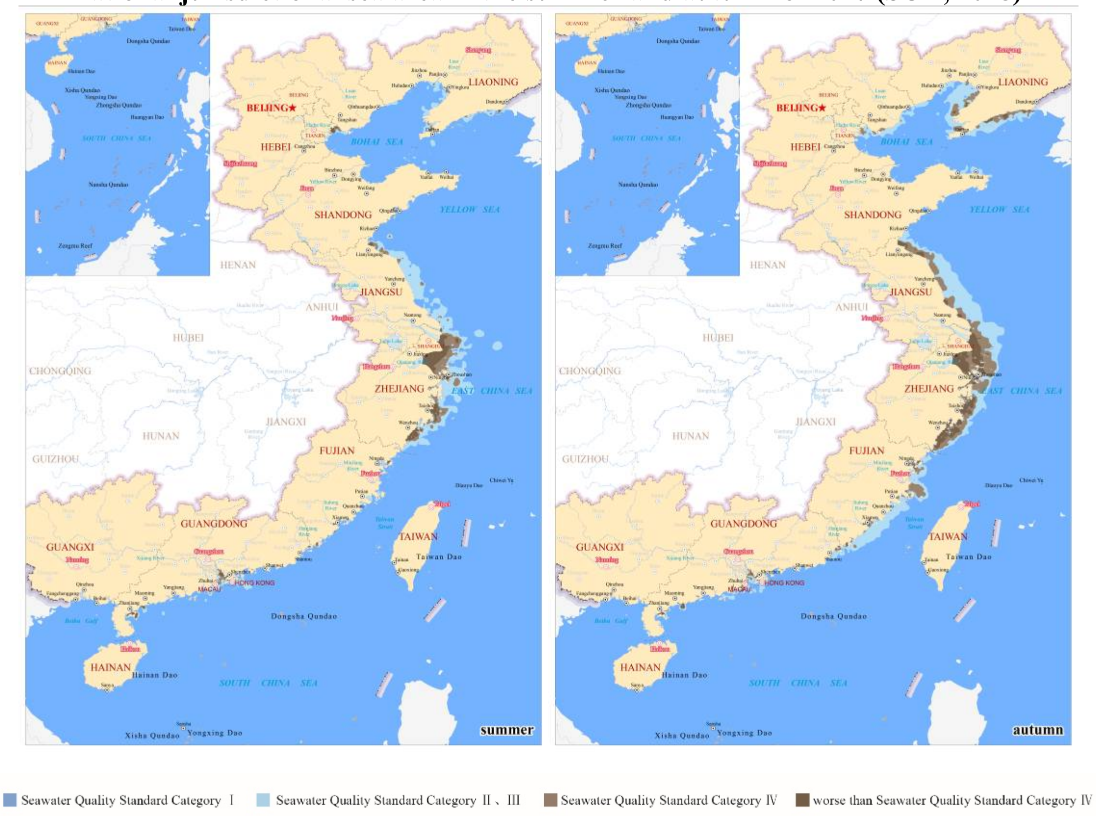


Figure 2. 2 Distribution of seawater quality categories of phosphate in the national jurisdictional sea area in the summer and autumn of 2017 (SOA, 2018)

Severe eutrophication areas were mainly located at the inshore areas (SOA, 2018). Nutrients related to anthropogenic activities are transported into the marine environment through the freshwater, atmospheric deposition and mariculture activities. Wastewater and sewage directly discharged into the sea is an important source. The main pollutants discharged from sewage outlets to the sea were TP (total phosphorus), COD_{Cr}, SS (suspended solids), and ammonia. Furthermore, atmospheric deposition is another pathway brings nutrients into the sea through wet or dry deposition in different forms, such gas or aerosol.

In the recent decade, China has made significant efforts in reduction of discharges, emissions, and contaminants, both air and water. The effect of these efforts is clearly visible in improve of seawater quality of the Bohai Sea and the eutrophic sea areas in the national jurisdictional sea area. However, eutrophication is still a problem in some areas, concerns about riverine inputs and atmospheric of nutrients should still remain.

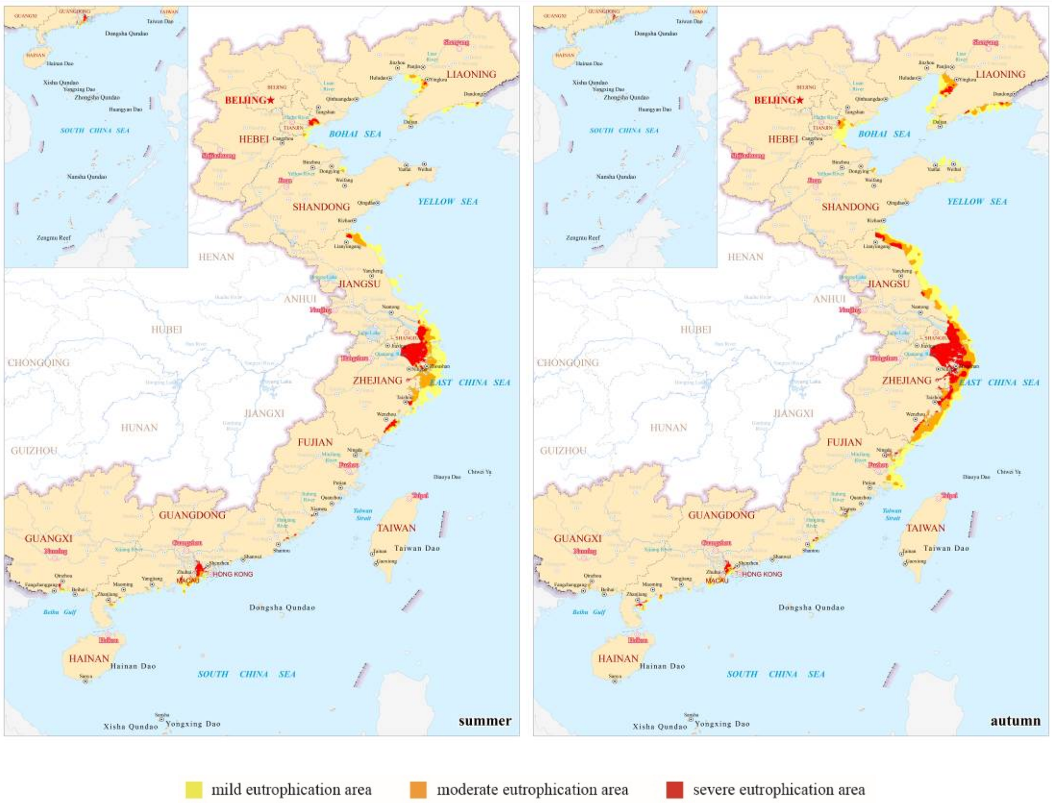


Figure 2.3 Distribution of the eutrophication status of the national jurisdictional sea area in the summer and autumn of 2017

2.2 *Marine litter*

Marine litter is a global issue, with increasing quantities of litter documented in recent decades. It includes any persistent, manufactured or processed solid material. Originating from sources both on land and at sea, marine litter comprises a wide range of materials, including plastic, metal, wood, rubber, glass and paper.

2.2.1 Macro litter in marine environment

The mean abundance of litter items on the seabed was 1 400 items/km^2. Of all the seabed litter, plastic was the largest, accounting for 74%, followed by glass and wood, accounting for 13% and 5%, respectively. Seabed litters were mainly plastic bags and bottles, glass bottles, and wood blocks. The abundance of floating litter in China's coast was two orders of magnitude less than those found in the North Pacific Gyre, and was of the same order of magnitude as those reported in samples from the North Atlantic coast and South Pacific subtropical coast, including the Caribbean Sea, the Maine Bay, and the Australia Coast. The maximum difference in mean abundance of litter in beaches among the studies was in the range of three orders of magnitude, which was much less than that of seawater. Compared to other reported in the worldwide, a relative low level of litter contamination was found on China's beaches.

2.2.2 Microplastics in marine environment

Plastic particles with diameters < 5 mm, which are called microplastics, are ubiquitously distributed in the marine environment, accounting for 13.2% of the global marine plastic debris mass and 92.4% of the number of global plastic pieces (Eriksen et al., 2014). There is growing concern over marine microplastics because of the increased bioavailability. Microplastics in marine environment is currently considered one of the most important global pollution problems of our time. China has been considered as one of the three biggest producers of plastic waste (Rochman et al., 2013a). Understanding the properties and distribution of plastics is useful in considering how microplastics impacts the social economy, what influence the items have on the marine ecosystem and how to target management.

- ***Microplastics in seawater***

According to the Bulletin of Marine Environmental Quality in China (SOA, 2018), in 2017, the average abundance of floating microplastics was 0.08 items/m3, and the highest abundance was 1.26 items/m3 in monitoring sections of China seas. The average abundances of floating microplastics in the Bohai Sea, Yellow Sea, East China Sea, and South China Sea were 0.04, 0.33, 0.07, and 0.01 items/m3, respectively. The main types of floating microplastics were granules, fibers, and fragments, and the main components were polystyrene and polypropylene.

- ***Microplastics in beach and sediment***

According to the Bulletin of Marine Environmental Quality in China (SOA, 2018), in 2017, the average abundance of beach microplastics was 245 items/m^2, and the highest abundance was 504 items/m^2. The main types were lines, granules, and fibers, and the main components were polystyrene and polypropylene. The mean abundance of microplastics in sediments was in the range of 25 – 47 897 items/m^2 for beaches and 15 – 3 320 items/kg for subtidal sediments. The maximum difference in mean abundance of microplastics in sediments among the studies was in the range of three orders of magnitude, which was much less than that of seawater. According to the previous reported studies, the microplastics abundance in beaches in Asia was significantly higher than those in America and Europe. Relatively high abundances were recorded in East Asia, including China, Japan, Hong Kong, and Korea.

- ***Microplastics in marine organism***

Some studies have reported the presence of microplastics in commercial seafood for human consumption, indicating a direct connection between the microplastics and seafood, especially the bivalve and fish (Rochman et al., 2013b; Rochman et al., 2015; Van Cauwenberghe and Janssen, 2014).

In total of 21 species of sea fish collected from a fishery of China were found to uptake microplastics in abundance of 0.2-26.9 items/g. Demersal species showed significantly higher abundance of microplastics than pelagic fishes. Microplastics were dominated by fiber in shape, transparent in color and cellophane in composition (Jabeen et al., 2017). Fibers were also the most common morphotypes of microplastics in fishes from the North Sea (Lusher et al., 2013). However, abundance of microplastics in pelagic fishes was higher than demersal fishes from the North Sea, Baltic Sea and English Channel (Rummel et al., 2016).

Li et al., (2015) investigated 9 commercial bivalves in China with microplastics ranged from 2.1 to 10.5 items/g. Multiple types of microplastics, including fibers, fragments and pellets, occurred in the tissue of all bivalves, and the most common size class was less than 250 mm.

According to Sun et al., (2017), microplastics were widely present in zooplankton of China coast. The average sizes of microplastics in the zooplankton were smaller than 200 μm in the Yellow Sea, the East China Sea and the South China Sea. Fibers were the dominant type of the microplastics

2.3 *SCCPs(Short-chain Chlorinated Paraffins)*

As the most complex halogenated contaminants, chlorinated paraffins (CPs) can be subdivided into short-chain ($C_{10–13}$, SCCPs), medium-chain ($C_{14–17}$, MCCPs), and long-chain chlorinated paraffins ($C_{18–30}$, LCCPs) according to the carbon atom number of chlorinated derivatives (Hilger et al., 2011). China is one of the largest producer of CPs in the world. According to de Boer et al. (2008), the CPs production in China was up to 600,000 tons by 2007. According to the recent literatures, the overall concentrations of CPs around the coastal area were higher than those from other countries and regions, for example a 6600 ng g^{-1} (dw) in sediment from the PRD coastal estuary has always been the highest concentration reported in literature all around the world (Chen et al., 2011).

Until now, most studies in China were conducted around the Bohai Sea and the concentrations were higher than those from Japan and west European areas (van Mourik et al., 2015). Furthermore, according to Ma et al., (2016), the riverine was the main source of SCCPs input and thereafter influenced the spatial distribution of SCCPs in Liaodong Bay. Further studies in Bohai demonstrate that the treated or untreated wastewater was an important direct or indirect input of SCCPs to the seawater.

Considerable amounts of SCCPs were detected in sediments from the nearshore regions of the Bohai Sea (97.6–1760 ng $g^{–1}$, dw) (Ma et al., 2014a), the Liaohe Estuary (64.9–1680 ng $g^{–1}$, dw) (Chen et al., 2014), Liaodong Bay (65.0–541 ng $g^{–1}$, dw) (Ma et al., 2014b), the mouth of the Daliao River (64.9–407 ng $g^{–1}$, dw) (Gao et al., 2010), and the PRD coastal estuaries of China (320–6600 ng/ g; mean: 2800 ng $g^{–1}$, dw) (Chen et al., 2011). Besides, the levels of SCCPs in the Liaohe River also exhibited a strong decreasing trend with increasing distance from the cities, implicating local industrial activities as the major emission source (Gao et al., 2012).

Ma et al., 2014 and Chen et al., 2016 have studied the influence of SCCPs on food web. The indicators of bioaccumulation and biomagnification of SCCPs in the marine organisms and marine food web hinted an ecological and health risks to organisms and humans, however to date, there is very limited data on CPs available for the risk managements in terrestrial wildlife and humans over the world.

2.4 *PBDEs (polybrominated diphenyl ethers)*

As one type of brominated flame retardants (BFRs), polybrominated diphenyl ethers (PBDEs) are extensively used in electronic appliances, plastics, furniture, and textiles as additives to prevent fire, and have received increased attention over the last two decades for their potential environmental risks. Since 2000, the extensive investigations on the occurrence and distribution of PBDEs in coastal environment have been conducted in South and East China (Chen et al., 2013; Mai et al., 2005). Totally, the concentrations of PBDEs in different marine matrixes were higher compared with other reports around the world, even with the developed countries (Yu et al., 2016). For example, the highest residual level of PBDEs reported in literature was found in the Pearl River Delta and several e–waste recycling areas in China. Obviously, the electronic manufacturing and e–waste dismantling industries was the main source of PBDEs around the coastal areas.

The concentrations of PBDEs around the coast of China also presented a typical regional characteristic and the overall concentrations were higher than those from other countries and regions (Yu et al., 2016). The highest concentration, with the value of 68 ng L^{-1}, was detected from the Pearl River Delta (Guan et al., 2007).. Because a lot of electronic manufacturing industries and e–waste dismantling areas exist in China coastal areas, the rainfall and the surface runoff are likely to take the atmospheric particulate and the soil into the coastal environment.

The concentrations of PBDEs displayed significant difference among the different sampling sites. According to the report of Li et al. (2012), PBDE distribution in the coastal Eastern China Sea (ECS) was related to the land–based inputs rather than the sediment characters. They were mainly from the coastal electronic waste dismantling/recycling and Yangtze River, and the coastal ECS is an important sink of the PBDEs in the world.

PBDEs residual levels in most coastal areas of China were also relatively lower than those of other countries. However, the concentrations of PBDEs from the polluted areas were comparable to/or even higher than those of developed regions (Table 2). According to the report by Shi et al. (Shi et al., 2009), the average concentration of PBDEs in fish samples collected from the electronic waste recycling plant in Qingyuan (Guangdong Province) was 153.0 ng g^{-1} (lw), and the mean value in waterfowls was up to 1165.2 ng g^{-1} (lw). Because of the high potential of bioaccumulation and biomagnification, the risk managements about PBDEs in terms of ecosystem and human health, especially in heavily polluted areas, should not be ignored.

2.5 *OCPs (Organochlorine Pesticides)*

Organochlorine Pesticides (OCPs) accounted for 80% of the total pesticides before1982 in China. According to the core sediment records of the Yangtze River Estuary, it was estimated that the total burdens of HCHs and DDTs in the inner shelf of the East China Sea were 35 tons and 110 tons, respectively. After 1983 (year of the official ban in China), those values were 13 tons and 50 tons, respectively (Lin et al., 2016).

The OCPs concentration in seawater and organisms presented an identical trend that the HCHs concentrations were higher than those of DDTs; whereas, the DDTs in sediment presented the opposite tendency. In the coastal areas of Fujian and Guangdong Province (locating in the South China Sea), the OCPs concentrations in water were relatively higher.

In the fishery along the throughout coastal line, from Tianjin in north to Wanning (Hainan Province) in south, the concentrations of DDTs and HCHs in bass muscle from southern fisheries were in general much lower than those from the northern. The ratios of OCP congeners suggested that technical DDT was not the main input and a recent usage of lindane or aged technical HCH residuals could be the source of HCHs. Expect for Quanzhou and Wanning, the consumption of bass were quite safe on the base of the maximum allowable fish assumption rate (Pan et al., 2016).

Comparing to open sea and ocean areas in the world such as Arctic Ocean, Pacific, and Berling Sea, the OCPs residual levels in the seawater of Chinese marginal seas were relatively higher because the usage in agriculture and disease control. However, The HCHs and DDTs concentrations in surface sediments much lower than those in some other Asian area, such as Vietnam, India and Singapore (Wu et al., 2015). The Asian Mussel Watch initiative by Monirith et al.(2003) revealed that China, along with Hong Kong and Vietnam, is one of the three countries having the highest DDT concentrations among 12 Asia-Pacific countries. Furthermore, the coastal region of central China is likely one of the most DDT- and HCH-polluted areas in the world in the context of the levels detected in mollusks (Zhou et al., 2014).

2.6 *PCBs (Polychlorinated Biphenyls)*

Polychlorinated biphenyls (PCBs) are one class of traditional persistent organic pollutants (POPs) targeted by the Stockholm Convention on persistent organic pollutants (POPs). The emissions from Chinese coking industry were 115 kg, less than 0.1% of the total UP-PCB emissions (Cui et al., 2013).

The concentrations of PCBs in the seawater and sediment sampling from some coastal areas of Dalian, Bohai Bay (Tianjin inshore) and Fujian Province (such as Minjiang River Estuary and Xiamen) were relatively higher than those in other coastal areas (Shi et al., 2016; Wu et al., 2016; Zhang et al., 2010). Similarly, the higher-leveled PCBs in fish and shell fish samples were detected collected from Dalian Bay, Bohai Bay and Pearl River Estuary, as Table 1 shown. The PCBs concentrations in the bass muscles of 9 Chinese fisheries (Tianjin, Qingdao, Lianyungang, Zhoushan, Ningbo, Wenling, Ningde, Quanzhou, Shantou, Shenzhen, Fangchenggang, Sanjiang and Wanning) were approximately 10 times lower than those fish taken from UK, USA and Japan.

PCBs may pose a health risk of a lifetime cancer to the coastal residents who consumed more seafood, so the carcinogenic risk factors was used to assess the health risk level derived from PCBs contamination (Xia et al., 2012). The PCBs concentrations in sediment sampling from Dalian Bay, West Harbor (Xiamen) and Pearl River Estuary exceeded the ERL value, suggesting that PCBs would have slight negative effects (Meng et al., 2017). The bioaccumulation in marine organisms in Hangzhou Bay and Yangtze River Estuary did not pose a significant health risk and the PCBs concentrations in air would not cause cancer via inhalation as well (Zhang et al., 2013; Adeleye et al., 2016).

Generally, the residual of PCBs in the marine environmental matrixes were relatively low to medium in the world, so that the adverse effects derived from PCBs were rarely reported in China. Some areas in high industrialization levels, such as Bohai Bay, Yangtze River Estuary and Pearl River Estuary were less contaminated in terms of PCBs concentrations in sediments, than Korean coasts, Singapore coasts, Sea lots of Trinidad, Cantabrian Sea (Spain), Bay of Biscay (France) and Guánica Bay (Puerto Rico, USA) (Adeleye et al., 2016).

2.7 *PAHs (Polycyclic aromatic hydrocarbons)*

Polycyclic aromatic hydrocarbons (PAHs) are a class of hydrophobic semi-volatile organic compounds in the environment, and originated mainly from incomplete combustion of fossil fuels and biomass. With the increase of fossil fuels consumption, the levels of PAHs in coastal environments are increasing. The overall concentrations of PAHs in different matrixes are comparable to some developed countries, especially in some harbour areas. For example the PAHs in sediments from the Dalian and Hong Kong harbour are similar to those from San Francisco Bay, USA (Li and Duan, 2015; Yao et al., 2009).

The difference of PAH concentrations in seawater among different regions are significant. In general, the PAH concentrations in the Bohai Sea are higher than those of the Yellow Sea, East Sea and South China Sea. The levels of PAHs along the marginal seas of China are comparable or slightly higher than those of other regions in the world depending on the different sea areas (Ya et al., 2017).

On a larger scale in China, PAH levels in sediments of the Bohai Sea were not statistically higher than those in the Yellow Sea and South China Sea sediments, which was probably influenced by the location of sampling sites, contents of organic matters in sediments, and local industrial structure of target areas, etc.

The results of vertical distribution in core sediments showed that, in general, PAH levels increased from the bottom to the surface, indicating the obvious influencing of human activities on the vertical distribution of PAHs. Most studies suggested that the concentrations of PAHs in core sediments began to increase gradually from 1960's. However, the different core profiles of PAHs among different sites indicated that regional characteristics (e.g. fuel consumption intensity, fuel types, economic development) also influenced the PAH levels and distribution (Xu et al., 2006).

2.8 *Antibiotics*

Antibiotics have been widely used as human and veterinary medicines to treat diseases and to promote growth in livestock and aquaculture, and increasingly released in to the aqueous environment. The occurrence, transformation and risks of antibiotics in aquatic systems are well-acknowledged environmental issues and have raised particular concerns (Baena-Nogueras et al., 2017; Luo et al., 2011). Importantly, these pollutants are pseudopersistent and have been proved to induce antibiotic resistance genes (ARGs), which have been recognized as a new emerging contaminant in environment. China is the largest producer and user of antibiotics in the world based on the market sales data. The total antibiotic usage in China for 2013 was estimated to be approximately 162000 tons. China consumed 150 and 9 times more antibiotics than the UK and USA, respectively. The large usage in China, as well as their incomplete elimination by metabolism (Campagnolo et al., 2002) and wastewater treatment (Chen et al., 2013a) have been resulted in the high emission into the environment. For instance, the total emission for 36 frequently detected antibiotics in China was estimated to be 53800 tons. Furthermore, the Yellow river, Huaihe river, and Yangtze river downstream basins received the discharge of the target antibiotics of more than 3000 tons (Zhang et al., 2015a).

As emerging contaminants, Antibiotics have been increasingly detected in environmental waters. Their presence in surface waters (including seawaters) has been reported in many countries including the United States (Kolpin et al., 2002), Europe (Loos et al., 2009), and Vietnam (Managaki et al., 2007). This is particularly relevant in China with their widespread occurrence in coastal areas (Ge et al., 2018; Ge et al., 2019; Luo et al., 2011). For example, sulfonamide antibiotics exist quite widely, with mean concentrations observed to range from 0.1 to 150.8 ng L-1 in the coastal waters of China through a variety of recent monitoring studies.

In general, the aquatic environment in China has relatively higher antibiotic contamination levels when compared with other countries around the world (Zhang et al., 2015b). The environmental concentrations for sulfonamides and tetracyclines in China are higher than in some European countries such as Italy and France. For the macrolides, roxithromycin had a mean concentration range of ND-150 ng/L in German rivers, while it was 0.05−378 ng/L in China. The measured environmental concentrations of fluoroquinolones (ciprofloxacin, norfloxacin, ofloxacin, and norfloxacin) in Italy (9 ng/L), USA (up to 120 ng/L), and Germany (20 ng/L) are much lower than those in China with concentrations up to 7560 ng/L, with the average for all fluoroquinolones being 303 ng/L.

2.9 *Summary*

Overall, China's rapid economic and social development has led to an acceleration in nutrient inputs to coastal waters. More than 80 percent of pollutants originates from terrestrial sources via point and non-point sources. Changes in the nutrients in coastal water were closely related to China's GDP growth rate, development pattern, population growth, as well as environmental protection policies and measures. The nutrient inputted to the sea increased rapidly during the end of the 1980s to the beginning of the 21st century, with a high rate of growth in real GDP. In the last decade, the increasing trend in nutrient inputs to the sea has been shifted, a steadily decreasing trend has been observed, and the status of coastal areas on eutrophication has improved over the last five years. Other than the nutrients, emerging contaminants and emerging issues about waters, sediment, and organism contamination have caused great concerns in China. The abundances of floating litter and microplastics in China's coast were the same order of magnitude as those reported in samples from the North Atlantic coast and South Pacific subtropical coast. Relatively high abundances of microplastics in water and sediment were recorded in the Estuaries and fishing harbors. More "true or really new" emerging contaminants would of course include many more types of contaminants such as pesticides, pharmaceuticals and personal care products, fragrances, plasticizers, hormones, flame retardants, nanoparticles, perfluoroalkyl compounds, chlorinated paraffins, siloxanes, algal toxins, various trace elements including rare earths and radionuclides, etc. Of these, SCCPs, PBDEs, OCPs, PCBs, PAHs, and antibiotics have been ubiquitous in China's coast, especially in the Bohai Sea. More work is still needed to elucidate the sources, status, fate, and potential threat to ecosystem and human health.

3. Pathways of the land-based pollutants into the ocean

With the development of economic activities and marine undertakings in coastal areas, a large amount of sewage and various harmful substances have entered the offshore sea of China, causing a certain degree of pollution. In recent years, the decline of aquatic resources in some sea areas, the ruin of beaches, and the decline of seashore aesthetics have all been related to sea area pollution. This section analyzes the main pathways of the pollutants interface with ocean, coastal and river based on recent data.

3.1 *Rivers and ocean outlets*

3.1.1 Main Riverine Sources of Pollutants

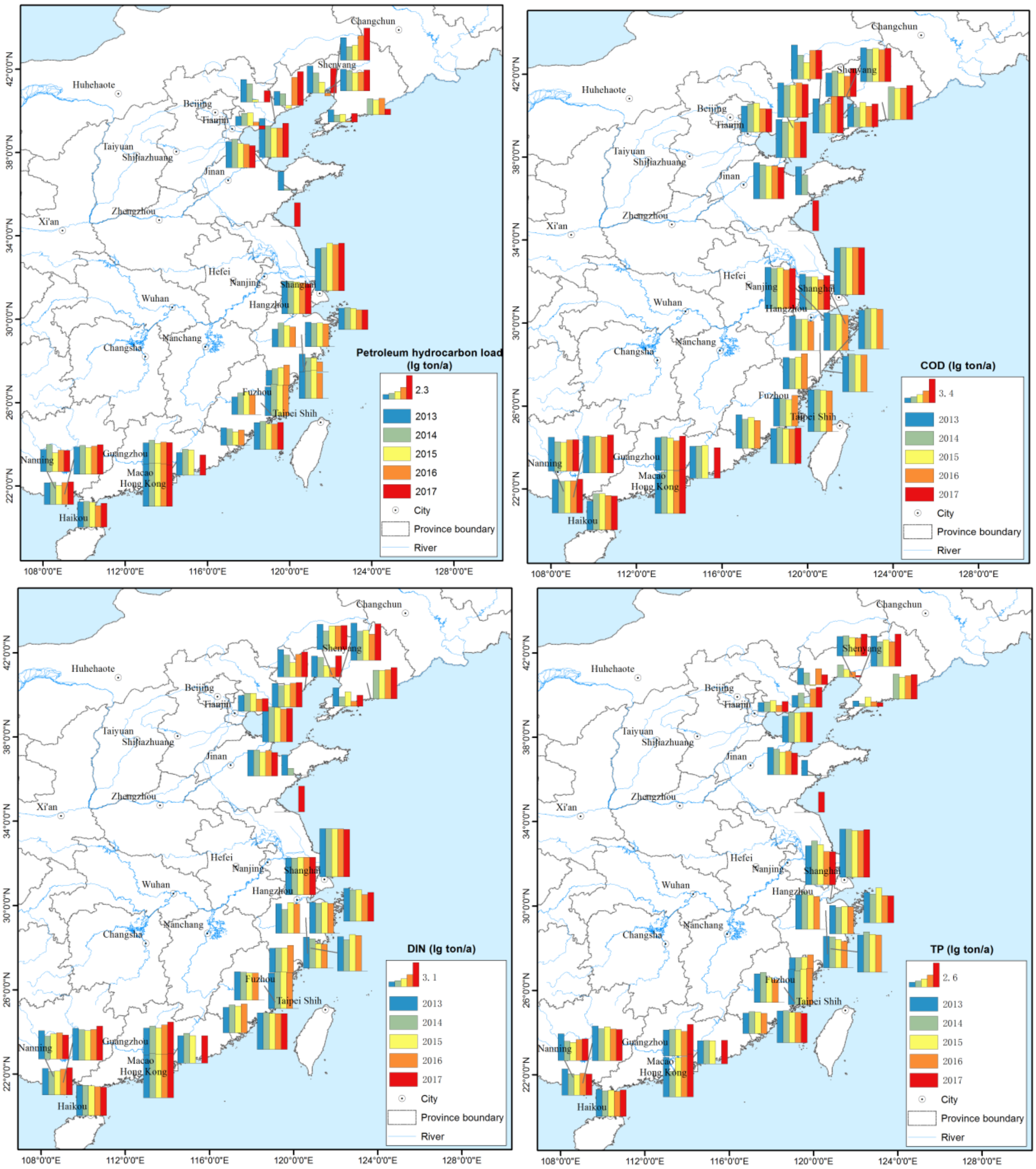
Of the 55 rivers monitored for several years, 44%, 42% and 36% rivers failed to meet Surface Water Quality Standard Category V during dry, wet and normal seasons, respectively (**Table3-1**). The main pollutants were chemical oxygen demand (COD_{Cr}), total phosphorus, ammonia nitrogen and petroleums.

Table3-1 The statistics for water quality categories of monitored riverine sections

Monitoring period	Water quality				Total
	I~III	IV	V	>V	
Dry season	6	18	7	24	55
Wet season	4	16	12	23	55
Average water season	6	15	14	20	55

The pollutant loads carried by 55 seagoing rivers monitored for several years were as follows: 13.3 million tons of COD_{Cr}, 150,000 tons of ammonia nitrogen (measured based on nitrogen), 2.1 million tons of nitrate nitrogen (measured based on nitrogen), 50,000 tons of nitrite nitrogen (measured based on nitrogen), 230,000 tons of total phosphorus (measured based on phosphorus), 50,000 tons of petroleums, 10,000 tons of heavy metals (including 2,826 tons of copper, 445 tons of lead, 6,974 tons of zinc, 105 tons of cadmium, and 49 tons of mercury) and 2,761 tons of arsenic.

The monitoring results from 2013 to 2017 indicated that, the total amount of nitrogen (ammonia nitrogen, nitrate nitrogen and nitrite nitrogen) input to the sea via rivers was 2.3-2.7 million tons each year, while the total amount of phosphorus was 0.18 – 0.27 million tons (SOA, 2018). The Changjiang River is the largest nutrient-transporting river among all of the Chinese rivers, followed by the Zhujiang River. Wastewater and sewage directly discharged into the sea is an important source of nutrients entering the coastal waters. The main pollutants discharged from sewage outlets to the sea were total phosphorus, COD_{Cr}, suspended solids, and ammonia.



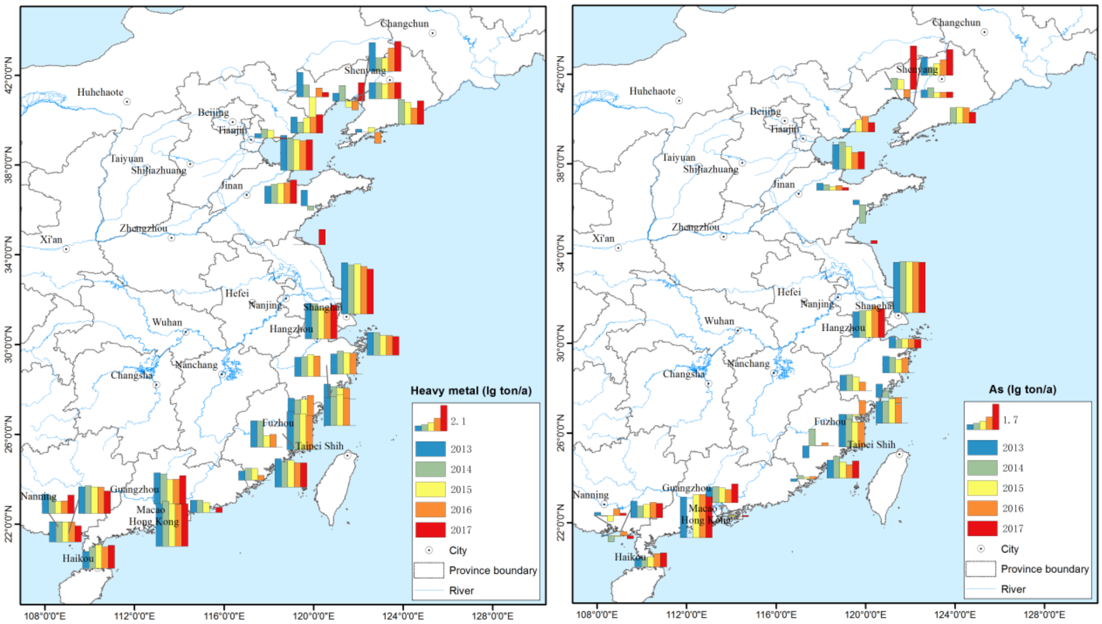


Figure 3.1 Distribution of the pollutant load in main riverine sources of China from 2013 to 2017 (SOA, 2018)

3.1.2 Environmental Quality of the Pollutant Discharge Outlets into the sea and the Adjacent Sea Areas

Results showed that, of the various types of emission outlets, the integrated source had the largest sewage load, followed by industrial source, and the least is the source of life (Table 3-2). Among the coastal provinces, Zhejiang has the largest sewage load, followed by Fujian and Guangdong, and Zhejiang has the largest COD load, followed by Liaoning and Shandong (Table 3-3).

Table 3-2 The pollutant load for various types of emission outlets in 2017

Outlet source	Number of outlets	Sewage load/10_4t	COD/t	Petroleum/t	NH_4-N/t	TN/t	TP/t	Cr/kg	Pb/kg	Hg/kg	Cd/kg
Industrial source	150	162 033	21168	153.0	711	3594	120	361.0	469.5	1.8	9.0
Source of life	59	73 385	24081	290.0	1946	7058	385	130.3	422.9	5.9	18.1
Integrated source	195	400 624	127165	463.3	8102	45973	1664	1843.5	2965.3	235.7	516.3

Table 3-3 The pollutant load of emission outlets in different coastal provinces in 2017

Province	Number of outlets	Sewage load/10_4t	COD/t	Petroleum/t	NH_4-N/t	TN/t	TP/t	Cr/kg	Pb/kg	Hg/kg	Cd/kg
Liaoning	34	52 534	19 742	278.4	3 282	6 209	264	138.4	30.3	31.1	--
Hebei	5	7 123	1 884	--	619	903	133	71.9	3.6	--	0.2
Tianjin	18	7 037	2 213	3.5	201	577	26	--	11.3	1.7	4.2
Shandong	47	64 771	19 637	36.5	860	6 106	203	157.6	389.3	64.9	66.1
Jiangsu	15	4 752	1 989	8.9	111	460	32	119.2	111.8	13.2	30.3
Shanghai	10	24 598	6 269	72.7	322	2 513	131	--	126.1	26.5	14.5
Zhejiang	85	206 877	74 702	271.1	2 585	23 480	524	1589.8	1 139.1	28.3	289.1
Fujian	59	156 516	18 870	86.9	936	5 981	229	167.5	135.7	51.9	16.7
Guangdong	66	71 487	14 529	70.9	1 014	6 008	328	22.9	201.6	14.5	4.0

Guangxi	38	11 901	5 043	12.9	289	1 630	205	67.6	1 664.8	9.7	117.7
Hainan	27	28 446	7 537	64.3	541	2 757	93	--	44.2	1.6	0.5

Among the 371 monitored land-based sewage outlets, 29% were industrial outlets, 43% were municipal outlets, 24% were sewage discharge rivers, and the remaining 4% were other types of sewage outlets. The percentage of standardized discharge for the monitored outlets in March, May, July, August, October, and November were 49%, 52%, 59%, 59%, 61%, and 62%, respectively. Throughout the year, standardized discharges occurred 57% of all monitored operations, which increased 2% compared with that in the previous year. The discharge levels of 119 sewage outlets were all compliant at each monitoring operations, and 76 sewage outlets discharged wastes at levels that were noncompliant with the standards at all monitoring operations. The main pollutants discharged from sewage outlets to the sea were total phosphorus, COD_{Cr}, suspended solids, and ammonia.

Of the various types of sewage outlets into the sea, the percentage of standardized discharge was 68% for industrial outlets, which was similar with previous year. The percentage of standardized discharge for municipal outlets and discharge rivers were 52% and 53%, which increased 2% and 9% compared with that of the previous year. The percentage of standardized discharge for other types of outlets was 62%, which decreased 3% compared with that of the previous year.

The environmental qualities of the adjacent sea areas of sewage outlets were generally poor. The adjacent sea areas of over 90% of sewage outlets could not meet the environmental protection requirements for their respective marine functional zones.

- ***Water Quality***

The water qualities of the adjacent areas to 79 sewage outlets in May and 80 in August were monitored. In May, the water bodies adjacent to 53 sewage outlets exceeded the Category IV standard,. In August, the water bodies adjacent to 56 sewage outlets (accounted for 70%) exceeded the Category IV standard, which accounted for 70% of the total monitored sewage outlets. The main pollutants were dissolved inorganic nitrogen, active phosphate, petroleum, and COD in the adjacent sea areas of sewage outlets. In some adjacent sea areas, water contained standard excessive concentrations of heavy metals and fecal coliform bacteria. The water bodies adjacent to 88% of sewage outlets could not meet the water quality standard for their respective marine functional zones.

- ***Sediment Quality Status***

The sediments quality in sea areas adjacent to 80 sewage outlets were monitored in August, among which 31 stations did not satisfy the sediment quality requirements of marine functional zones. The main pollutants were petroleum, copper, chromium, mercury, and sulfide.

- ***Organism Quality Status***

The organism quality monitoring results of shellfish collected from the adjacent areas of sewage outlets indicated that 67% of samples could not meet the organism quality standard for their respective marine functional zones. The main pollutants were fecal coliform bacteria, Cd, Hg, Zn, and As. In some adjacent sea areas, Cu, Pb, and petroleum hydrocarbons exceeded the standard.

- ***Trends of Environment Quality of Adjacent Sea Areas***

The monitoring results from 2013 to 2017 indicated that over 75% of seawater adjacent to sewage outlets were classified as Category IV or worse than IV each year. The main pollutants were inorganic nitrogen and active phosphate. The percentage of the adjacent sea areas with sediment qualities that met the requirements of the Marine Sediment Quality Standard Category I increased during these years.

3.2 *Air*

3.2.1 Pollutant contents in marine atmospheric aerosols

Atmospheric deposition is another pathway bring nutrients into the sea through wet or dry deposition in different forms, such gas or aerosol. Monitoring of pollutants in marine aerosols was carried out at 15 stations, namely, Laohutan in Dalian, Daheishi in Dalian, Yingkou, Panjin, Huludao, Qinhuangdao, Tanggu, Dongying, Penglai, Beihuangcheng, Xiaomaidao in Qingdao, Lianyungang, Shengshan in Zhoushan, Beishuang in Fujian, and Dawanshan in Zhuhai. The highest concentration of NO_3--N in aerosols was observed at the Qinhuangdao Station at 6.3 μg/m^3, and the lowest was at the Dawanshan Station at 0.9 μg/m^3. The highest concentration of NH^{4+}-N in aerosols was found at the Yingkou Station at 6.0 μg/m^3, and the lowest was at the Dawanshan Station at 1.4 μg/m^3. The highest Cu concentration (72.5 ng/m^3) was found at the Huludao Station, and the lowest (6.5 ng/m^3) was at the Beihuangcheng Station. The highest Pb concentration (116.0 ng/m^3) was detected at the Huludao Station, and the lowest (11.5 ng/m^3) was at the Zhoushan Shengshan Station.

During 2013 and 2017, the total amount of nitrogen (ammonia nitrogen, nitrate nitrogen and nitrite nitrogen) input to the sea via wet deposition of atmosphere was declined generally, while the total amount of heavy metal (copper and lead) showed fluctuation changes (SOA, 2018).

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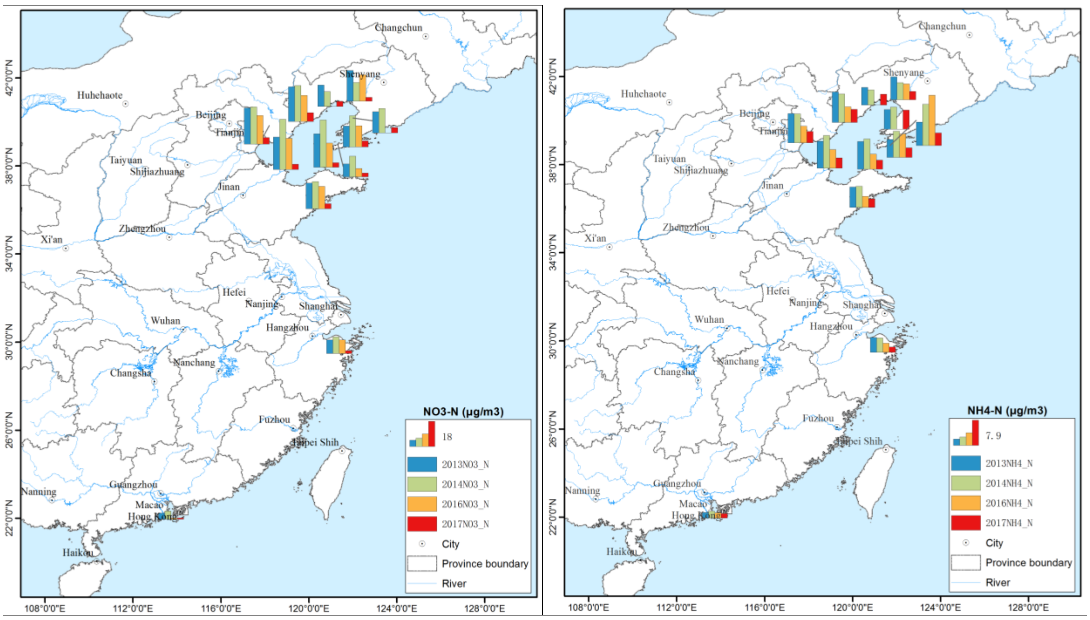

Figure 3.2 Concentrations of Inorganic Nitrogen in Aerosols at Various Monitoring Stations from 2013 to 2017

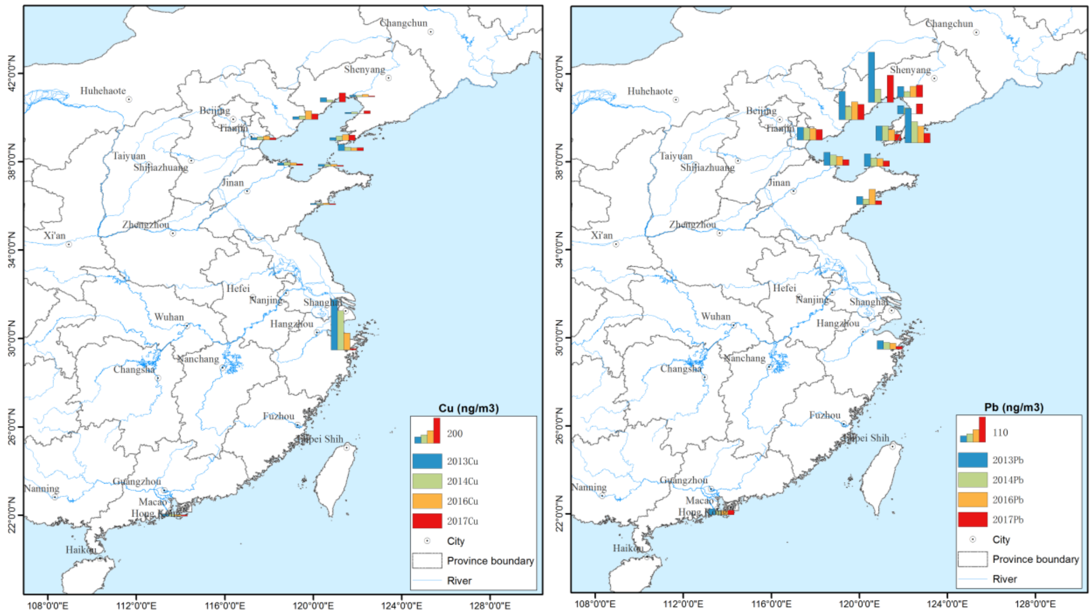

Figure 3.3 Concentrations of Copper and Lead in Aerosol at Various Monitoring Stations from 2013 to 2017

3.2.2 Wet deposition of atmospheric pollutants in the Bohai Sea

Wet deposition of atmospheric pollutants is one of the important channels for the natural and man-made chemical elements transporting to the ocean, and the dissolved elements in the rain are easy to absorb and enrich by marine plants and animals, which have a direct effect on the marine ecological environment. Studies have shown that plankton in the ocean have a rapid response to nutrients in rainwater, and primary productivity increases rapidly after wet deposition events. In the yellow sea, 65% of the dissolved inorganic nitrogen and 70% of the dissolved inorganic phosphorus are transported by atmospheric wet deposition.

Monitoring of the wet deposition fluxes of atmospheric pollutants was conducted at Daheishi in Dalian, Yingkou, Panjin, Qinhuangdao, Tanggu, Dongying, Penglai, and Beihuangcheng. The highest wet deposition fluxes of nitrate-N and ammonia-N were observed at the Daheishi Station at 1.3 and 0.7 t/(km^2•a), respectively. The lowest wet deposition fluxes of nitrate-N and ammonia-N were observed at the Penglai Station at 0.2 and 0.4 t/(km^2•a), respectively. The highest wet deposition flux [3.7 kg/(km^2•a)] of Cu was found at the Dongying Station, and the lowest [0.7 kg/(km^2•a)] was at the Tanggu Station. The highest wet deposition flux of Pb [0.8 kg/(km^2•a)] was found at the Beihuangcheng Station, and the lowest [0.1 kg/(km^2•a)] was at the Dongying Station.

The monitoring results indicated that, during 2013 and 2017, the total amount of nitrogen (ammonia nitrogen and nitrate nitrogen) input to the sea via wet deposition of atmosphere was 5.4 – 35.4 tons/(km^2·a), while the total amount of copper was 5.9 – 17.4 kg/(km^2·a), and the total amount of lead was 2.3 – 13.2 kg/(km^2·a) (SOA, 2018). The Tanggu station is the largest nutrient (ammonia nitrogen and nitrate nitrogen) transporting station among the stations in the Bohai Sea. The Yingkou station is the largest heavy metal (copper and lead) transporting station among the stations in the Bohai Sea.

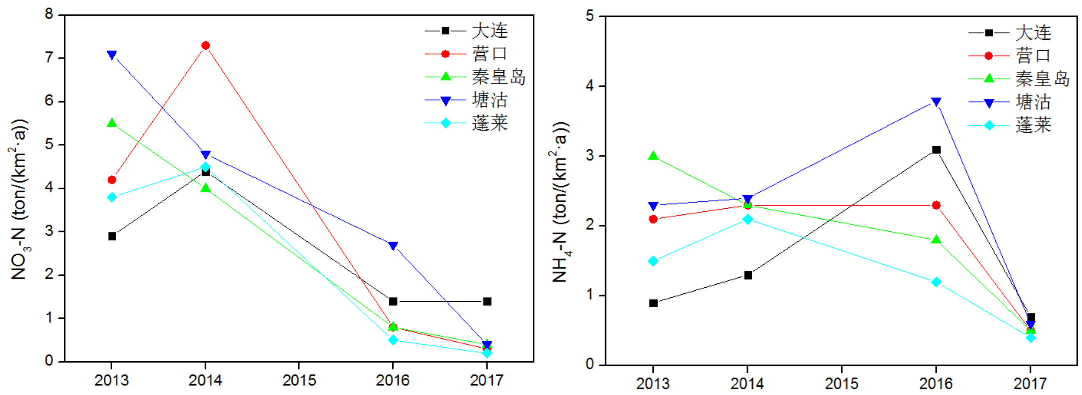

Figure 3.4 Wet Deposition Flux of Inorganic Nitrogen at Various Monitoring Stations in the Bohai Sea from 2013 to 2017

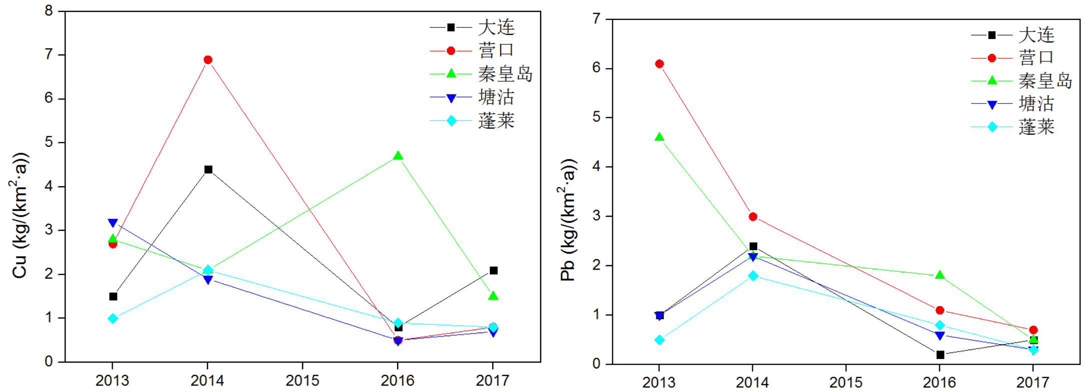

Figure 3.5 Wet Deposition Flux of Copper and Lead at Various Monitoring Stations in the Bohai Sea from 2013 to 2017

3.3 *Ground water*

Submarine Groundwater Discharge (SGD) is increasingly considered to be one of the important pathways for terrestrial chemicals, such as nutrients, trace elements and pollutants, to enter the ocean. China's research on SGD started late, but a lot of work has been carried out so far. China's SGD research is mainly concentrated in the estuaries of the Yellow River, the Yangtze River and the Pearl River. It belongs to the delta coast type. The loose sediments are widely distributed and thick. The coastal aquifers have better water-rich conditions and the groundwater input is more obvious (Peterson et al., 200; Gu et al., 2012; Liu et al., 2012). Jiaozhou Bay, Xiakou Bay and Hong Kong Tulu Bay, both are bedrock coasts, sandy coasts, and small river deltas, the input of groundwater is very uneven (Guo et al., 2008, 2011; Liu et al., 2013; Tse & Jiao, 2008). On the east coast of Hainan Island, with varying degrees of mangroves and corals, groundwater input has special significance for mangroves and corals (Su et al., 2011; Wang et al., 2015). The delta of the Minjiang River estuary is not obvious, belonging to the coast of the triangular port, and the input of groundwater is very limited (Zhang et al., 2012).

The researchers used the radium isotope tracing technique to study the groundwater discharge from the seabed, and analyzed the transport flux of the source elements they carried, and then evaluated the possible environmental effects (Wang, 2017). The study areas include semi-closed aquaculture bay - the easternmost Sanggou Bay in the Shandong Peninsula, the relatively closed aquaculture lagoon - the Laoye Sea and the Little Sea in the eastern part of Hainan Island, and shelf edge sea under the influence of the great river. The SGD fluxes of the three types of study areas are listed in Table 3.4. Results showed that the

SGD flux as a whole is Sanggou Bay > lagoon > East China Sea. The comparison shows that the effect of tidal dynamics is more pronounced in the semi-enclosed bay than in the relatively closed lagoon system, so in the relatively closed water environment of the Grand Sea and the Small Sea, the amount of seawater circulation caused by a single ocean drive is limited. Whether in semi-enclosed bays, relatively closed lagoons or open shelf systems, SGD plays a very important role in its biogeochemical cycle: in research areas with small river flow, small area, relatively closed and semi-closed, SGD is the main input source, and the nutrient flux input from it can reach more than 40% of the total input of nutrients, even up to 98%, in the area where the river flow is large, the area is large and open, the nutrient flux input by SGD is equivalent to the nutrient flux delivered by the river, and it is also an important input source that cannot be ignored.

Table 3.4 A comparison of SGD and its driven DIN, DIP, and DSi fluxes in different study areas of this word

Study area	Regional characteristics	River flow	SGD	Tidal-driven SGD	SGD/River		
		$10^7 m^3 a^{-1}$	$10^7 m^3 d^{-1}$	$10^5 m^3 d^{-1}$	DIN	DIP	DSi
Sanggou Bay	Semi-closed aquaculture bay	17~23	2.59~3.07	75~100	21.0	1.5	5.8
Laoye Sea	Relatively closed aquaculture lagoon	1.26	0.17	1.5~1.9	2.6	0.1	79.7
Little Sea		83.6	0.18	0.6~2.2	0.9	3.5	0.9
East China Sea Shelf	Shelf edge sea under the influence of the great river	1.14×10^5	$(1.14\sim5.42)\times10^5$	-	0.8	2.2	1.2

4. Impact on marine ecosystems from marine pollution

Marine ecosystem is the largest ecosystem on the earth, and plays important roles in regulating the climate system, supporting rich biodiversity, and sustaining the development of human-beings. Marie ecosystem has a rich diversity of habitats, such as estuaries, sea grass beds, salt marshes, tidal flats, mangroves, coral reefs and shelves, and provides multiple beneficial services to human society. The health of marine ecosystem is crucial for the sustainable development of global economy. The fisheries and aquaculture industry generate US$252 billion annually, and support the livelihoods of between 58 million and 120 million people. Fish from the sea provide 3.1 billion people with over 20 percent of their dietary protein (UN Environment, 2019).

Marine ecosystem has been considered as a vast and resilient system to pressures, but is now subject to significant changes under multiple stressors. The principal drivers of the changes are ocean warming, acidification, pollution, increasing use of oceans for food production and transportation, increased nutrient and sediment run-off, and marine litter etc. The impacts of these driving factors will produce significant negative impacts on marine ecosystems and their services. In the First World Ocean Assessment, the detrimental impacts on the health of marine ecosystems have been clearly addressed[2]. The 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development' has been listed as the 14^{th} Sustainable Development Goals (SDG14) to protect marine ecosystems and resources[3].

[2] The First Global Integrated Marine Assessment. 2016. https://www.un.org/Depts/los/global_reporting/WOA_RegProcess.htm

[3] SDG14, 2018. https://sustainabledevelopment.un.org/sdg14

China is an important coastal country with a continental coastline of more than 18,000 km, and the claimed jurisdictional sea area is 3.0 million km^2. Marine ecosystem supports a wide variety of habitats for marine organisms, and different resources for peoples' livelihoods. The wealth of natural marine resources and the enormous value of marine ecosystem services are important contributor to the nation's socio-economic development. With the continuing development of social economy and rapid urbanization along the coast, marine ecosystem is facing increasing threats of pollution. Apparent changes of marine ecosystem, such as the occurrence of harmful algal blooms, hypoxia, alteration of food web structure, degraded habitat conditions, loss of biodiversity, have been reported.

4.1 *Nutrient pollution and eutrophication*

Excessive land-based nutrient input into the sea will lead to serious problems of nutrient pollution and eutrophication, and subsequently affect different marine ecosystems. Many coastal regions around the world, particularly the coastal waters of East Asia and Western Europe, have series problems of eutrophication.

Coastal eutrophication is mainly caused by the increased use of fertilizer from agriculture. In the regions with intensive fertilizer use, such as Asia, Europe and the USA, huge amounts of dissolved inorganic nitrogen (DIN) will export to aquatic systems via rivers. It has been estimated that approximately 60 Tg nitrogen (N) flows to the world's oceans through rivers every year. Compared to phosphorus (P) fertilizers, N fertilizers have a rapid increase due to the capacity for anthropogenic N synthesis. In China, the production of N fertilizer increased nearly 5 fold in the last four decades. Another important source of nutrients is the animal waste. The animal production facilities are estimated to produce huge amounts of N pollution in the reduced forms of N, such as ammonia, urine and other dissolved organic N. Mariculture is an important source of nutrients in the sea, especially for the reduced forms of N. Atmospheric deposition is also increasing due to many sources, like volatilization of NH_3 from agricultural lands and animal operations.

In China, nutrient pollution is mainly confined in the estuaries and embayment, such as the Liaodong Bay, Bohai Bay, Changjiang River estuary, Hangzhou Bay and Pearl River estuary. Increasing nutrient input into the sea lead to significant changes of the concentrations and structure of nutrients in seawater. In the river mouth of the Changjaing River, concentration of N increased about 4 times compared to the 1960s (Zhou et al., 2008), while the concentration of P had little change, and silicate exhibited a decreasing trend. As a result, the stoichiometry of nutrients in seawater also changed significantly. In the Changjiang River estuary, the N/P ratio increased significantly while the Si/N ratio dropped from 4 to 1. In the Bohai Sea, the N/P ratio was about 3 in the middle 1980s, but increased drastically to over 25 by the 21st century. Over the same period, Si/N ratio showed a dramatic decrease (Wang et al., 2018). In the Yellow Sea, the N/P ratio also rose rapidly from around 5 in the middle 1980s to around 20 in the middle 2000s, while the Si/N ratio dropped from around 2 to 1 over the same period. In the Pearl River estuary of the South China Sea, however, the N/P ratio exhibited a decreasing trend from the end of the 1990s. The forms of N exported to the sea also changed significantly. More than half of the N fertilizer used throughout the world now is urea. The increasing use of organic forms of nitrogen are likely to promote the growth of small flagellates and lead to different ecological consequences compared to the dissolved organic nitrogen (DIN).

The occurrence of harmful algal blooms (HABs) is the most significant consequence of coastal eutrophication (Glibert, 2017). The direct responses to nutrient enrichment in marine ecosystems are the increasing level of chl-*a* and algal blooms that sometimes are harmful or noxious. An increasing number of HAB events have been recorded in the coastal waters of China during the last 2 decades (Figure 4.1, Yu et al, 2018). Before the 1990s, the recorded number of HABs is quite limited. Most of the HABs were caused by non-toxic diatoms, and affected a relatively small sea area. Since the year 2000, the recorded number of HAB events has reached 50−80 every year. Large scale HABs have been recorded in many different regions of the China Seas. In the East China Sea, for examples, intensive blooms of different dinoflagellate species (red tides) have been recorded from the beginning of the 21st century. The blooms of dinoflagellates can last from early May to the middle June each year, and affect a large sea area up to 10 000 km^2. The HABs of dinoflagellates, such as *Prorocentrum donghaiense* and *Karenia mikimotoi*, are harmful to both aquaculture industry and marine ecosystems. For instance, the red tide of *K. mikimotoi* in 2005 led to mass mortality of cultured fish in the sea area around Nanji Island, and the economic loss was estimated to be 30 million RMB. Another red tide of *K. mikimotoi* in 2012 destroyed the aquaculture industry of abalones along the coast of Fujian Province, and led to the economic loss around 2 billion RMB (nearly $300,000,000). Dinoflagellate *P. donghaiense*, although non-toxic, has strong inhibition effects on reproduction of the keystone zooplankton species *Calanus sinicus* in the East China Sea. In the Bohai Sea, a tiny pelagophyte *Aureococcus anophagefferens* formed large-scale brown tides from the year 2009, and became a recurrent phenomenon in this region later on. In 2010, the bloom affected a sea area over 3000 km^2 and destroyed the scallop culture industry in this region, which led to economic loss of 200 million RMB (about $30,000,000). In the South China Sea, large-scale red tides of haptophyte *Phaeocystis globosa* started to appear from the late 1990s in Zhelin Bay, Guangdong Province. The red tide caused mass mortality of cultured fish, and the economic loss was estimated to be 70 million RMB (about $10,000,000). From the year 2010, intensive red tides of *P. globosa* started to appear in Beibu Gulf, an isolated sea area previously pristine to HABs in the northwestern part of the South China Sea. Red tides of *P. globosa* occurred in northern Beibu Gulf in 2014 and 2015 and posed potential threats to the operation of cooling systems of a nuclear power plant. Besides the HABs of microalgae, the harmful algal blooms of macroalgae, such as the green tides of *Ulva prolifera*, have been recorded in the southern Yellow Sea from the year 2007, and led to negative impacts on the west coastline along the Yellow Sea. Many studies have suggested that the occurrence of HABs in the China Seas is closely related with coastal eutrophication caused by nutrient pollution (Zhou et al., 2008). Huge amounts of N and P discharged into the sea in different forms aggravated the status of coastal eutrophication, with different features in different regions. For example, the Changjiang River estuary and its adjacent waters is characterized by high concentration of nitrate and high N/P ratio and N/Si ratio. In the coastal water of Qinhuangdao of the Bohai Sea, however, the organic forms of nitrogen are more prominent. This will lead to the proliferation of different types of HABs.

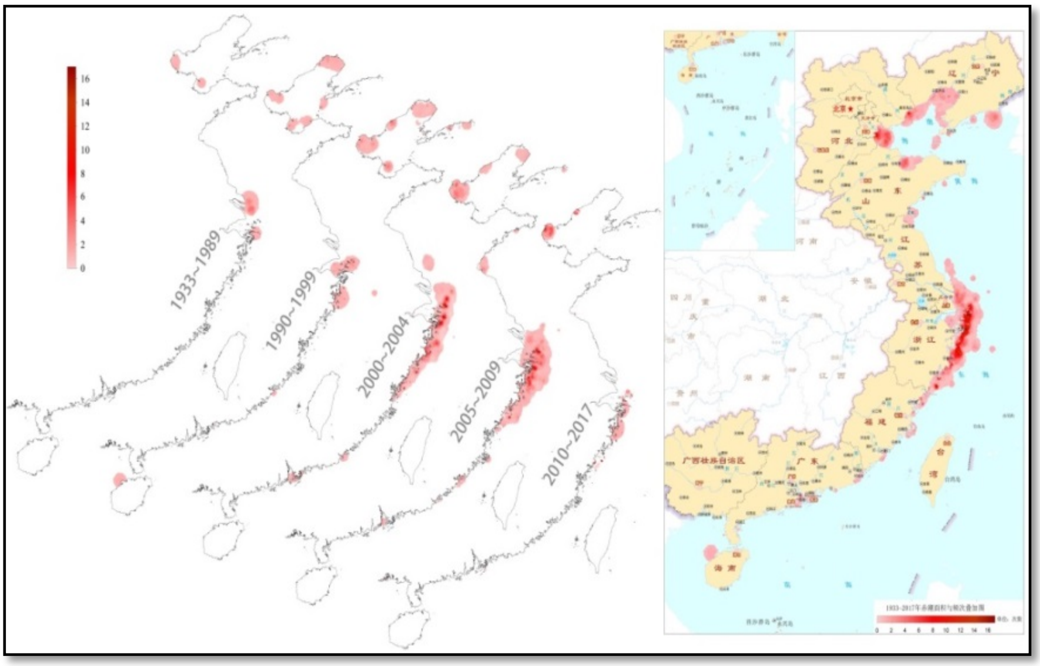

Figure 4. 1 Distribution patterns of red tides recorded during the period between 1933 and 2017

Hypoxia is another significant consequence of coastal eutrophication, which could cause the collapse of marine ecosystems and fishery resources (Rabalais et al., 2010). Coastal eutrophication will promote the growth of algae in the sea and cause increasing deposition of organic matter into the bottom. The degradation of organic materials lead to consumption of dissolved oxygen (DO) in seawater at the bottom and result in adverse effects on benthic animals. Under the extreme condition, “dead zone” will form at the bottom. It has been estimated that a total sea area of more than 245,000 km^2 is affected by dead zone around the world. The Gulf of Mexico and the northwestern shelf areas of Black Sea are the two most well-known hypoxic areas. Studies have shown that status of hypoxia gradually deteriorated in the sea area adjacent to the Changjiang River estuary over the past several decades (Wang, 2009; Wei et al., 2007), and the probability of hypoxia in summer has increased by 90% from 1990 onwards. DO level at the bottom of the Pearl River estuary also followed a decreasing trend related to the excessive input of N, leading to a marked increase of hypoxia-tolerant foraminifera from 1970. Recently, intensive oxygen deficit has been observed at the bottom of the Bohai Sea. Besides bottom water hypoxia, acidification of the bottom water is another consequence of coastal eutrophication, which could have adverse effects on benthic communities.

Increased nutrient loading also results in losses of biodiversity and habitat, changes of ecosystem structure, and degradation of ecosystem services. Nutrient over-enrichment is regarded as a major cause for the decline of seagrasses, coral reefs, mangroves and salt marshes. In the Bohai Sea, in association with the increase of phytoplankton standing stock (as indicated by chl-*a* concentration) from the 1980s to the beginning of the 21st century, the proportion of large net-collected phytoplankton dropped dramatically over the same period. Besides, the dominancy of dinoflagellates, such as *Ceratium* spp., gradually increased from the 1990s to the 2000s. In the sea area adjacent to the Changjiang River estuary, the number of benthic animal species decreased evidently together with the increasing proportion of polychaetes, which have short life cycle and high tolerance to environmental stresses. The massive occurrence of jellyfish in the Yellow Sea and Bohai Sea are also partially attributed to coastal eutrophication.

4.2 *Microplastics*

Marine plastics and microplastics (MPs), which has been found in nearly all oceans at all depths, received increasing attention recently (Egbeocha et al., 2018). It has been estimated that the total input of plastic litter into the sea amounts to some 8 million tonnes annually, and 80 percent of which originates from land-based sources. Plastics are synthetic organic polymers, such as polypropylene (PP), polyethylene (PE), polystyrene (PS), polyvinylchloride (PVC) and polyethylene terephthalate (PET), with different properties. MPs are commonly defined as small particles with a diameter between 1~5 μm, in the forms of particles, fibres or granules. MPs in the sea could be divided into primary microplastics that are products for domestic and industrial use, and secondary microplastics generated by breaking of larger plastic items in the sea.

It has been believed that marine plastic litter can result in significant ecological impacts from entanglement and ingestion. A large number of filter feeding organisms, such as copepods, bivalves, fish and whales, could actively or passively ingest MPs in seawater (Guzzetti et al., 2018). Besides, MPs can act as a vector for the transport of other pollutants and pathogens, and lead to more risks of the organisms ingesting on MPs. Due to the unique features of MPs, they could actively absorb and concentrate other pollutants, particularly persistent organic pollutants (POPs) in seawater and transfer them through food chains. This process could lead to potential impacts on marine ecosystems.

The growing presence and abundance of MPs in the sea has potential adverse effects on the health of both marine organisms and human-beings. Researches have revealed some negative impacts of MPs on marine organisms. The chronic exposure to MPs, for examples, can lead to decreases of food ingestion, growth, and fecundity of copepods. The ingestions of MPs by economic fish species also pose potential risks to human health.

MPs have been widely detected in seawater and sediment of the China Seas, including the sea area adjacent to the Changjiang River estuary in the East China Sea, the Bohai Sea, coastal waters of the South China Sea, and northern Yellow Sea etc (Zhu et al., 2018). The investigations MPs and polycyclic aromatic hydrocarbon (PAHs) in the Bohai Sea and the Yellow Sea indicated a high risk of transferring PAHs by MPs (Mai et al., 2018). Besides, MPs were also detected in zooplankton, shellfish and fish samples. The demersal species generally has relatively higher abundance of MPs compared to the pelagic species. However, little studies revealed any direct impacts of MPs on marine animals or ecosystems in the China Seas so far.

4.3 *Persistent organic pollutants (POPs) and endocrine disrupting chemicals (EDCs)*

Some halogenated organic chemicals, such as organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), polybromodiphenyl ethers (PBDEs), hexabromocyclododecanes (HBCDs), dechlorane plus (DP) and perfluoroalkyl substances (PFASs), have been listed as persistent organic pollutants (POPs) in the Stockholm Convention (Liu et al., 2016). High levels of POPs are usually found in the sea areas near populated, urbanized and industrialized regions, and land-based activities have been considered as the major source of POPs in the coastal seas.

POPs have negative impacts on different marine organisms in various ways. Some POPs, like lindane, PBDEs or PFOA, could inhibit the growth of algae through their acute toxic effects. The POPs could also inhibit the enzyme activity and interfere the immune system of marine organisms. PBDEs has been reported to affect the gene expression of fish. Field investigations also revealed potential toxic effects of DDE on the eggs produced by brown pelicans (*Pelecanus occidentalis*) off the southern California. Some studies also illustrated the bioaccumulation and biomagnification of POPs via marine food web, which will lead to significant risks to animals at the high trophic levels.

Some organic pollutants, including butyltins, natural (estrone [E1], 17β- estradiol [E2]) and synthetic (nonylphenol [NP]) estrogens, atrazine, dichlorodiphenyltrichloroethane (DDT)-related compounds, polychlorinated dibenzo-p-dioxin/dibenzofurans (PCDD/F), and coplanar polychlorinated biphenyls (co-PCBs), have special toxic effects of endocrine disruption, and are considered collectively as endocrine disrupting chemicals (EDCs). Butyltins, for example, will cause imposex of marine gastropods, thus lead to sterility and extinctions of gastropod populations under the severe contamination condition.

To protect the coastal ecosystems and human health, some selected marine animals, like mussels, have been used as indicator to reflect the long-term variation and accumulation in marine organisms. The monitoring programs such as “Mussel Watch” of the US, and documented the long term changes of POP pollution status in the sea.

China plays an important role in implementation of the Stockholm Convention to reduce and eliminate pollution of POPs. Monitoring of POPs has been systematically conducted in the coastal waters of China. According to the review of past investigations on POPs in the Bohai Sea and the Yellow Sea (Meng et al. 2017), it was found that high hydrophobic compound like OCPs, PCBs, PBDEs and HBCDs were mainly present in sediment, while the relatively hydrophilic PFASs were mainly detected in seawater. High concentration of POPs were detected mainly in the coastal waters of the Bohai Sea and northern Yellow Sea. Potential risks of POPs were evaluated. At the Pearl River estuary in the South China Sea, biomagnification of PCBs, PBDEs and DDE were found in Bombay duck and Tapertail anchovy. In Jiulongjiang River of Fujian province, the ecological risk of POPs were generally low, and only PAH may pose some ecological risks (Wu et al., 2017).

For EDCs, the butyltin compounds have been widely detected along the coast of China, and imposex of gastropods have been reported. High proportion of sterile individuals (10–27%) were predicted in the sea areas near Dalian, Lianyungang, Xiamen, Shenzhen, Beihai, Haikou, and Dongya (Figure 4.2). The highest incidences of female sterility were found along the coast between Shantou and Shenzhen in the South China Sea. The incidences of intersex have been documented in wild population of clams *Mactra veneriformis* collected from Bohai Sea, reflecting the potential impacts of EDCs. According to an investigation in the Bohai Sea, EDCs had relatively high ecological risks to estuarine animals compared to PAHs.

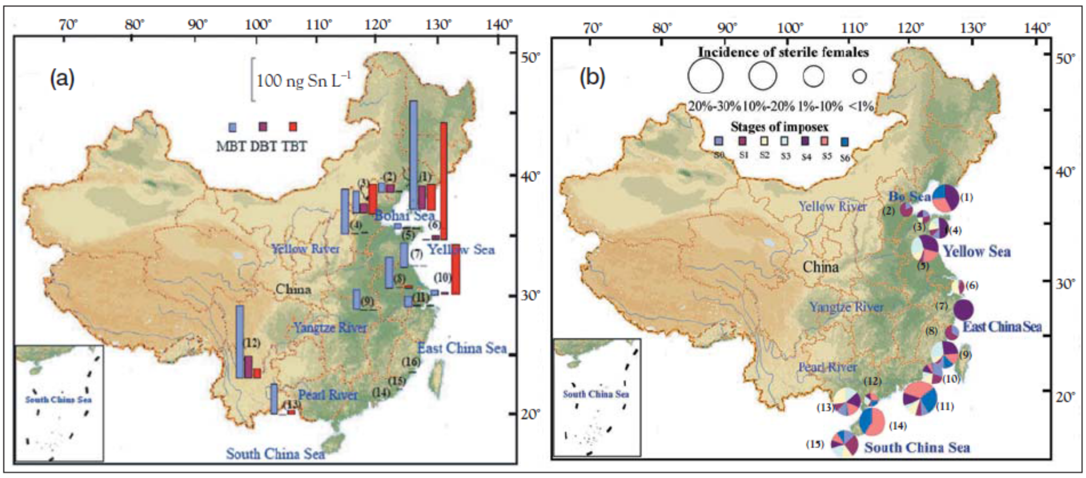

Figure 4.2 Concentrations of butyltin compounds (a) and relative proportions of imposex stage and predicted incidence of sterile females in coastal waters of China (An and Hu, 2012).

4.4 *Antibiotics*

Antibiotics have been widely used to treat infectious disease in humans, and in livestock and aquaculture operations as well. Aquatic environments are major pools for antibiotics, which have been widely detected in the coastal waters. Antibiotics released into marine environment may pose potential risks to the health of marine ecosystem (Brandt et al., 2015). So far studies on the impacts of antibiotics mainly focused on their acute or chronic toxic effects, and the ecosystem risk assessment methodologies for antibiotics have been developed using different organisms. The knowledge on their impacts on microorganism communities, however, are still quite limited. A growing body of evidence indicates that the selection of antibiotic-resistant bacteria may occur in the environment. The rapid and widespread increase of antibiotic resistance genes (ARGs), which is considered as an emerging pollutant, has been accelerated in recent years.

Many investigations have been performed in the coastal regions of China Seas, including Bohai Bay, Beibu Gulf, Jiaozhou Bay, Laizhou Bay, Yantai Bay, Liaodong Bay, and Shenzhen Bay, to detect targeted antibiotics (Figure 4.3). In an investigation in 2017(Lu et al., 2018), 7 out of 13 target antibiotics were detected in coastal water samples. Detected norfloxacin (NFC) and sulfamethoxazole (SMX) had high ecological risks, while non of the antibiotics exerted apparent risks on the health of human-beings. Strains of *Vibrio vulnificus* and *V. parahaemolyticus* isolated from seafood in China have been tested for their resistance to antibiotics, and some strains showed resistance or intermediate resistance to various antibiotics, which could pose risks to the health of human-beings (Jiang et al., 2019). .

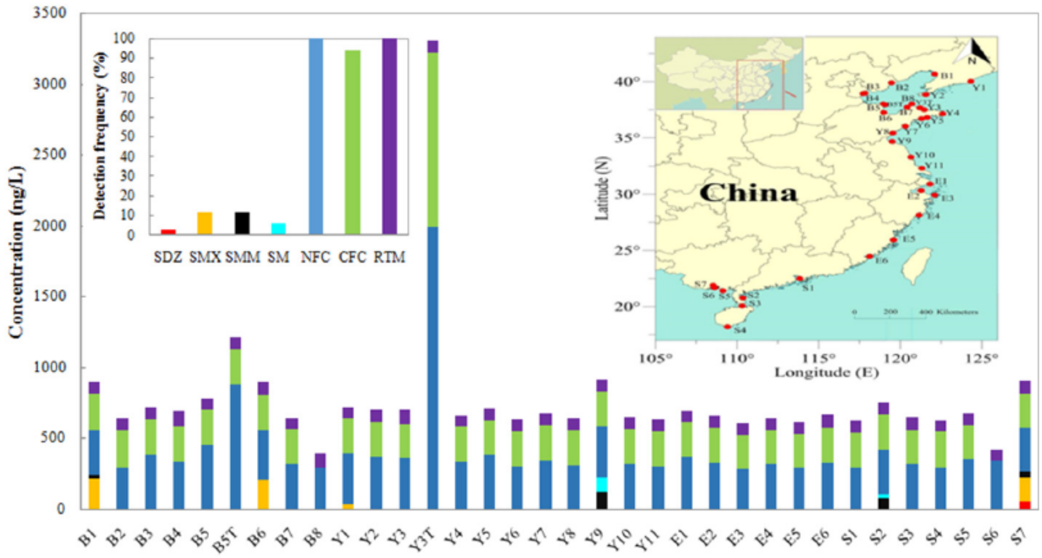

Figure 4.3 Distribution, concentrations and detection frequencies of target antibiotics in coastal waters (Lu et al, 2018)

4.5 *Heavy metals*

The naturally occurring heave metals, including zinc (Zn), copper (Cu), chromium (Cr), lead (Pb), nickel (Ni), arsenic (As), mercury (Hg), and cadmium (Cd), are increasingly present in marine environment as a result of anthropogenic activities. The heavy metals in marine environment are potentially bioavailable and toxic to aquatic biota at high concentrations.

Many laboratory studies revealed potential acute or chronic toxic effects of heavy metals to phytoplankton, zooplankton, fish and benthos. In some coastal regions, the concentration of heavy metals could reach the level of causing toxic effects. The toxic effects of heavy metals in marine environment could be modulated by many factors, such as seawater salinity, or content of organic compounds in sediment. For marine animals at high trophic levels of the food web, metals from bioaccumulation and bio-magnification processes are somehow more important than those uptaken from seawater.

In China, prevention and management of heavy metal pollution has been set as one of the key goals of government. The production and consumption of heavy metals however, are still increasing, and metal pollution in the sea will remain an important issue. Using coral skeleton as an indicator, it was found that concentrations of metals Cr, Cu, Cd, Ba, Pb and U in Hainan Island have risen in the recent 140 years. Another study in Liaodong Bay indicated rapid increase of Cd, Hg, Zn and Pb concentrations after the late 1970s. Concentrations of heavy metals in seawater and sediment are generally higher in southern part of the China Seas compared to the northern part, particularly for Pb and As. The coastal regions in the Bohai Sea like Jinzhou Bay, however, have high concentrations of Cd and Hg. In Jinzhou Bay, high concentration of heavy metals may pose potential ecological risks to the marine ecosystem.

4.6 *Interactions between marine pollution and climate change*

Marine pollution mainly occur in the coastal region, with complex interactions with other stressors, such as climate change (including warming and acidification due to increasing level of CO_2), overfishing and habitat losses (Alava et al, 2017; Lu et al, 2018). These stressors could affect food webs, marine ecosystems, and the ecological services simultaneously. Moreover, the processes of climate change are likely to affect the exposure and bioaccumulation of marine pollutants. Studies indicated that, with global warming, exposure of apex predators in arctic to PCBs and mercury may increase due to the retreating of sea ice. The climate change will also affect status of marine nutrient pollution in many different ways. Nutrient input into the sea, for example, is tightly coupled with freshwater discharge, which is driven by regional climate variability and global climate change. Therefore, it’s necessary to have a comprehensive understandings on the complex interactions between marine pollution and other stressors like climate change.

4.7 *Summary*

Marine environment are facing increasing impacts from pollution, including nutrients, heavy metals, oil spill, POPs, EDCs, antibiotics, marine litters and MPs. The coastal eutrophication resulted from nutrient pollution is undoubtedly the most severe marine pollution issue in China, and lead to significant ecosystem changes like HABs, hypoxia and other ecosystem changes. EDCs, oil spill and heavy metal pollution will lead to apparent negative impacts in confined sea area. Consequences of some emerging marine pollution issues, such as MPs or antibiotic resistance genes (ARGs), only have limited studies so far.

To have a better understanding on the consequences of marine pollution, a holistic, integrated monitoring and assessment of the marine environment needs to be fostered to achieve “Good Environmental Status”. Besides, the complex interactions between marine pollution and other stressors, particularly climate change, required for an integrated approach to evaluate the health status of marine ecosystems, to guide the implementation of marine pollution controlling activities.

5. Existing governance measure in China on coastal and ocean pollution

The People's Republic of China, as a contracting party of the relative international conventions, including: UNCLOS, London Conventions, 1996 Protocol, MARPOL Conventions, CBD, FAO Code of Conduct for Responsible Fisheries, Basel Convention, Stockholm Convention, Rotterdam Convention and Minamata Convention, has been working to improve national laws, regulations and policies to fulfill the obligations under those conventions. After 20 to 30 years of construction, China has set up a basic legal and regulatory framework for the conservation of the marine environment and sustainable use of living resources.

The domestic legal sources of China on marine pollution heavily rely on its administrative laws and regulations while some other important provisions are reflected in its civil law, criminal law, procedural law and their judicial interpretations. Policies in particular formulated by the Central Committee of CPC or the State Council despite of their non-legally binding nature may play critical role for marine environmental stake-holders as well, which should not be underestimated.

5.1 *National Laws*

The fundamental legislation in the marine environmental protection area is the Marine Environment Protection Law of PR China (hereinafter referred to as "The Marine Environment Protection Law"). The Marine Environment Protection Law has undergone four amendments (1999, 2013, 2016 and 2017) since its promulgation on August 23, 1982. The law currently has 10 chapters, including General Provisions, Supervision and Control over the Marine Environment; Marine Ecological Protection; Prevention and Control of Pollution Damage to the Marine Environment Caused by Land-based Pollutants; Prevention and Control of Pollution Damage to the Marine Environment Caused by Coastal Construction Projects; Prevention and Control of Pollution Damage to the Marine Environment Caused by Marine Construction Projects; Prevention and Control of Pollution Damage to the Marine Environment Caused by Dumping of Wastes; Prevention and Control of Pollution Damage to the Marine Environment Caused by Vessels and Their Related Operations; Legal Liabilities and Supplementary Provisions, for a total of 98 articles. The law is PR China's basic law for the protection of marine environment, which provides an overall regulation on pollution control, ecosystem protection and resources conservation. It provides that the administrative department in charge of environment protection under the State Council, shall guide, coordinate and supervise the nation-wide marine environment protection work and be responsible for preventing and controlling marine pollution damages caused by land-based pollutants and coastal construction projects.

The law established many legal systems on the protection of the marine environment. On pollution control, the law set up the marine environmental quality standard system, total quantity control system and regional limits system. For the key sea areas where the State has established and put into practice the system of controlling the total sea-disposed pollution discharge. In key sea areas where the indicators for the control of the total quantity of key pollutants discharged into the sea are exceeded, the environment protection administrative departments shall suspend the approval of the environmental impact reports (forms) for the construction projects which will newly increase the total quantity of corresponding types of pollutants discharged into the sea. Prevention and control of pollution is the core part of the Marine Environment Protection Law, which is stipulated in five chapters separately as: (1)

Prevention and Control of Pollution Damage to the Marine Environment Caused by Land-based Pollutants; (2) Prevention and Control of Pollution Damage to the Marine Environment Caused by Coastal Construction Projects; (3) Prevention and Control of Pollution Damage to the Marine Environment Caused by Marine Construction Projects; (4) Prevention and Control of Pollution Damage to the Marine Environment Caused by Dumping of Wastes; and (5) Prevention and Control of Pollution Damage to the Marine Environment Caused by Vessels and Their Related Operations. The 2016 revision of the law specifically requires that Vessels and their relevant operations shall take effective measures to prevent marine environment pollution, while increasing the provisions "An administrative department of maritime affairs and other relevant departments shall strengthen the supervision and administration of vessels and their relevant operations."

For maritime pollution incidents, the law requires the State to draw up State contingency schemes to cope with major marine pollution accidents.

Besides the laws analysed above, there are some other laws that are closely related to the conservation of the marine environment. The Law on Prevention and Control of Air Pollution regulates the pollution from atmospheric deposition. The Law on Prevention and Control of Water Pollution regulates the land-based pollution by carrying out the discharge standard system, total quantity control system and discharge permit system. And the Law on Environmental Impact Assessment provides the EIA as a useful tool to control the environmental impact of coastal and sea projects etc.

5.2 *National Regulations*

In order to implement the laws issued by the National People's Congress and its Standing Committee, or to regulate the issues which have not been addressed in the current laws, the State Council, administrative departments of central government, local people's congress and local people's government issued about 80 regulations and rules of all levels, which to a large extent enriched the legal system on marine environmental protection.

5.2.1 Regulations issued by the State Council

In order to implement the laws issued by the National People's Congress and its Standing Committee or to regulate the issues which have not been addressed in the current laws, the State Council issued about 15 national regulations since the 1980s. Of these 15 regulations, 6 regulate marine pollution from different sources, such as vessel, ship breaking, coastal and marine engineering projects, dumping, oil exploitation. This shows that pollution is the areas that attract more attention of the State Councils.

a. Administrative Regulation on the Prevention and Control of Pollution Damages to the Marine Environment by Vessels

b. Administrative Regulation on the Prevention and Control of Pollution Damages to the Marine Environment by Coastal Engineering Construction Projects

c. Administrative Regulation on the Prevention and Treatment of the Pollution and Damage to the Marine Environment by Marine Engineering Construction Projects

d. Regulations of the People's Republic of China on the Control over Dumping Wastes into the Sea Waters

e. Regulations of the People's Republic of China Concerning Environmental Protection in Offshore Oil Exploration and Exploitation.

f. Regulations on Prevention of Environmental Pollution by Ship Breaking.

5.2.2 Department Rules Issued by the Administrative Departments under the State Council

To fulfil the obligations in laws and regulations and carry out the management duties set down by the State Council, the administrative departments which have authorities over the sea issued about 28 department rules within the last 30 years. Of these 28 department rules, 7 of them are related to pollution control regarding pollution from vessels and related activities, exploitation of offshore oil, and dumping.

Table 5.1 Department Rules Issued by the Administrative Departments under the State Council

No.	Name	Issuing Authority	Date Issued	Effective Date
1	Provisions of the People's Republic of China on the Administration of Prevention and Control of Marine Environmental Pollution by Vessels and Their Operations (2017 Amendment)	Order No. 15 [2017] of the Ministry of Transport	2017.05.23	2017.05.23
2	Provisions of the People's Republic of China on the Administration of Emergency Preparedness for and Emergency Response to Vessel-Induced Pollution to the Marine Environment (2018Amendment)	Order No. 21 [2018] of the Ministry of Transport	2018.09.27	2018.09.27
3	Measures for the Implementation of the Regulations of the People's Republic of China on the Dumping of Wastes at Sea (2016 Amendment)	Order No. 64 of the Ministry of Land and Resources	2016.01.05	2016.01.05
4	Measures for the Implementation of the Regulation of the People's Republic of China on the Administration of Environmental Protection for Offshore Oil Exploration and Exploitation (2016 Amendment)	Order No. 64 of the Ministry of Land and Resources	2016.01.05	2016.01.05
5	Measures for the Administration of Entrusted Issuance of Licenses for Dumping Wastes into the Sea	Order No. 25 of the Ministry of Land and Resources	2004.10.08	2005.01.01
6	Measures for the Administration of Fishery Pollution Accident Investigation Qualification	Ministry of Agriculture	2004.04.12	2004.04.12
7	Provisions on the Procedures of Fishery Water Pollution Accident Investigation and Handling	Order No. 13 of the Ministry of Agriculture	1997.03.26	1997.03.26

Besides the national laws and regulations, the local coastal provinces and cities have also issued local laws and local regulations on marine environment protection. These laws and regulations have further improved the marine environment protection legal system.

5.3 *Policy Issued by the National and Local People’s Governments*

The Government of PR China has issued a variety of national policies and launched a number of projects to protect the marine environment, implement laws and regulations and comply with its obligations under the international conventions. Many of the policies and projects can be found in plans developed by national and local governments. The general plan developed by the National Development and Reform Commission (NDRC) under the State Council is the Five-Year Plan for Economic and Social Development of the People’s Republic of China. There are also plans focused on a specific area, for example, the National 13th Five-year Plan for Protection of Ecological Environment developed by the Ministry of Environment Protection, The National 13th Five-year Plan for Marine Economy

Development by the NDRC and State Oceanic Administration. Local government, according to the national plan and based on their own situations, may develop specific plans, for example, the 13th Five-year Plan for Marine Development of Jiangsu Province, Marine Ecological Red Line Protection Plan of Jiangsu Province (2016-2020).

Governments at various levels strictly control the land-based pollutants discharged into the sea, only if they meet both the discharge standards and the total amount of pollutants that can be discharged. Governments are working on the establishment of an early warning mechanism to prevent the pollutants discharged from exceeding the carrying capacity of the marine environment.

The Nearshore Pollution Control Plan is implemented to improve the quality of ecological environment in estuary and nearshore areas. The target of the plan is to eliminate the land-based discharge from rivers whose water quality fall below Grade 5 in coastal provinces before the year 2020.

Thirteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China clearly proposes the implementation of the "Blue Bay" remediation project, the "South Mangrove and North Tamarix" wetland rehabilitation project and the "Ecological Island" restoration project. The implementation of the "Blue Bay" remediation project will optimize the production, ecological and living space layout of the bay and coastal wetlands, control the discharge of land-based pollution, strengthen the ecological improvement and restoration of the bay, and create beautiful seascape of the bay. The project will accelerate the restoration of coastal wetlands and beaches, and to stop the degradation and loss of coastal wetlands in China. The ecosystem services of the bay and coastal wetlands will be enhanced.

The Action Plan for the Comprehensive Management of the Bohai Sea requires the improvement of the ecological environment quality of the Bohai Sea as the core target. For major actions including land-based pollution control action, sea-based pollution control action, ecological protection and restoration action, and environmental risk prevention actions will be implemented and the Bohai Sea ecological environment will be ensured to be no longer degraded. By the end of 2020, 73% of the coastal waters in Bohai Sea will attain the good sea-water quality (Class 1 and Class 2 sea-water quality) requirements, the natural shoreline retention rate will remain at around 35%, the coastal wetland remediation and restoration area will be no less than 6900 hectares, and the coastline remediation is about 70 kilometres.

5.4 *Institutional development*

Ecological civilization was listed along with economic, political, cultural and social progress as one of the five goals in the country's overall development plan at the 18th National Congress of the Communist Party of China in 2012. Respect, protect, and stay in tune with nature. Ecological conservation is vital not only to sustained, healthy economic development, but also to political and social progress, and must therefore be given a position of prominence and incorporated into every aspect and the whole process of economic, political, cultural, and social development. See that mountains, waters, forests, and farmlands are a community of life. Based on the integrity and systemic nature of ecosystems and the way they work, it is necessary to take into consideration all the elements of the natural ecosystem – both hills and their surrounding areas, both above and under the ground, both land and sea, both upper and lower river basins -and work to protect them in their entirety, restore them systematically, and take a comprehensive approach to their governance in order to preserve ecological balance by strengthening the ability of ecosystems to circulate. The 13th Five-Year Plan period is crucial for China to accelerate eco-civilization construction and to complete the construction of the moderately prosperous society. The key tasks include developing green economy to promote economic transformation and upgrading, improving efficiency of energy and resource to build environment-friendly and resource-efficient society, implementing ecological construction projects to promote ecosystem services capability, solving outstanding environmental problems that threaten people's health, setting and strictly observe ecological red line, promoting new-type urbanization to coordinating urban and rural development, carrying out national ecological assets accounting and building up monitoring platform for ecological assets. China set up several goals for marine eco-civilization to be achieved during its 13th five-year plan (2016-2020). During the 13th five-year period, more than 2000 km shoreline and 66 bays will be remediated, more than 85km^2 coastal wetland will be restored. Expansion of the MPA coverage in the sea areas under national jurisdiction is to 5%.

Gulf chiefs-China has been launching new mechanism to protect marine ecology. China has initiated a pilot mechanism of appointing "gulf chiefs" to tackle pollution on coastlines and offshore areas. The protection mechanism for maritime pollution control outlined by the SOA is similar to the approaches of "river chiefs" and "lake chiefs" which have been widely adopted nationwide since 2016 and have achieved visible results in combatting pollution. Under the mechanism, top officials at provincial, city, county, and township levels are appointed as chiefs, accountable for the effects of water pollution control. The SOA selected the province of Zhejiang and cities of Qinhuangdao, Qingdao, Lianyungang, and Haikou to pilot the gulf-chief mechanism at the start of 2017.The pilot should be extended and expanded in the near future, and a national standard system to evaluate the work of gulf chiefs should be established based on the pilot results.

Ecological redlines. In 2017, China issued “Several Opinions on Delineating and Strictly Protecting the Red Line of Ecological Protection”, pointing out that the improvement of the quality of the ecological environment and the conservation of the ecological function is the core targets. Given the need for systematic governance of mountains, forests, farmland, rivers, and lakes, the ecological protection red line will be delimited and strictly guarded. The red lines will governance the important ecological space and ensure the ecological service not degrading, area not reducing, nature not changed. By the end of 2020, the national red line of ecological protection will be fully defined, and the red line system of ecological protection will be generally established. The ecological space of the country will be optimized and effectively protected, the ecological function will remain stable, and the national ecological security pattern will be more perfect. By 2030, the layout of the ecological protection red line will be further optimized, the ecological protection red line system will be effectively implemented, the ecological function will be significantly improved, and the national ecological security will be fully guaranteed. The marine ecological red line system refers to the institutional arrangements for the maintenance of marine ecological health and ecological security, defining important marine ecological functional areas, ecologically sensitive areas and ecologically vulnerable areas as key control areas and implementing strict classification and control. The Nearshore Coastal Pollution Prevention and Control Program requires that the ecological protection red line area of the coastal waters be no less than 30%.

5.5 *Gaps in the Current Laws and Policies*

Although laws and policies have been much improved in the last ten years, there are still some existing gaps which prohibit China from fully implementing its obligations in the international conventions and protect its marine environment and resources.

Lack an integrated ecosystem-based view. The ecological character of a marine ecosystem determines that the ultimate goal of conservation and management is to maintain its ecological integrity. This requests that any of the conservation and management activities must be designed based on or derived from an ecosystem-based point of view. Although the principles of "determine the land-based discharge amount based on the carrying capacity of the sea" and "promote land and marine development in a coordinated way" have been raised frequently as the guiding principles for major national policies, due to the limitation of the administrative system, these principles have not been implemented well. The current laws, regulations, policies and plans are enacted based on administrative sectors with inadequate communication and coordination among each other.

Lack of laws in protection of resources and ecosystem. After the examination of current environmental laws and policies, it was found that in China, laws and policies in pollution control were relatively well developed, while laws and policies in the protection of resources and ecosystem are relatively weak. For example, lack of a national wetland law or regulation remains a challenge for China's wetland conservation, especially for establishing the institution of specific mechanisms for wetland management, including those related to conservation concession, ecological compensation, supplementing water supply, and water pollution treatment. The prevention and control of marine debris has been focused on more frequently by the international community in recent years. As to the Marine Environment Protection Law, the articles relative to marine ecosystem protection which occupied only 10% is rather limited comparing with the articles concerning the control and prevention of marine pollution. The limited ratio is inconsistent with the requirements of ecological civilization progress. Although China has a set of legal systems in prevention and control of all kinds of marine pollution and a national law regulating solid waste which is the major pollutant source for marine debris, the regulation of marine debris hasn't been well established, because the current solid waste legislation hasn't been integrated with the coastal zone management laws and policies. The legal system to prevent and control marine debris needs to be strengthened in the coastal zone management laws.

Lack of Detailed Implementation Rules. After more than 30 years of legal construction since the issuance of the Marine Environmental Protection Law in 1982, the legal framework offering a rough line to protect the marine environment, and utilization of natural resources has been established. But many legal systems are very general with no implementation rules followed, which to a large extent influenced the implementation effect. This left the law a big room for improvement.

Lack of a Cross-sector Implementation Mechanism. As the "global" feature of environmental problems gets more and more apparent and the interaction among these problems goes deeper within an ecosystem, the issues discussed recently by the international environmental conventions intersect with each other, especially climate change, wetland degradation, biodiversity loss, fishery resources depletion, etc. Yet in China, the responsibilities to implement international conventions are assigned to different administrative sectors based on their duties with no or not enough coordination in implementations. Different implementing bodies separately carry out the rights and obligations for China as a participating country under international conventions. The disadvantage of this system is that the resources spent by the implementation bodies can't generate synthetic effects, therefore, lots of duplication in efforts and activities existed, causing a waste of limited administrative resources.

6. Ongoing national and international ocean initiatives to combat ocean pollution

By 2050, the planet will need to provide food, health, jobs and energy to sustain a population of 9 billion people. A healthy ocean is essential to life on Earth, from the smallest plankton to the largest marine mammals, and is the underpinning of ecosystems and human well-being. It is estimated that some 40 per cent of the global population live within coastal communities and 3 billion people rely on the ocean for their livelihoods. As our dependency on ocean increase, so have political engagement and various policies and initiatives have been and are under development to combat marine pollution.

6.1 *International measures*

6.1.1 Global ocean governance framework and international legal instruments

Multiple international institutions, legal frameworks exist at global level for ocean governance, including mechanisms to target marine pollution. In table 1 an overall overview of legal and institutional frameworks can be found.

Table 6.1 Legal and institutional framework

International Institutions
International Maritime Organization The International Seabed Authority The World Trade Organisation The Food and Agriculture Organization The World Bank/Global Environment Facility UN Development Programme
Legal framework at the global level
United Nations Convention on the Law of the Sea (UNCLOS) Agreement relating to the Implementation of Part XI of UNCLOS The United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (the Straddling Stocks Agreement) The Convention on Biological Diversity The United Nations Framework Convention on Climate Change (UNFCCC) The Kyoto Protocol The Paris Agreement FAO instruments The 1993 FAO Agreement to promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas The 1995 FAO Code of Conduct for Responsible Fisheries IMO treaties The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 The 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter The Convention on Migratory Species The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade The Stockholm Convention on Persistent Organic Pollutants The Minamata Convention on Mercury Proposed international legally binding instrument (on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction

Many of those instruments are relevant to marine pollution. UNCLOS is the global legal framework for ocean governance, there are two implementing agreements, on deep seabed mining and highly migratory fish stocks respectively under UNCLOS. A third Implementing Agreement on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ) is currently under negotiation and is expected to be finalized in 2020.

Part XII of UNCLOS deals with 'Protection and preservation of the marine environment' and requires states to take all measures necessary to prevent, reduce and control pollution of the marine environment from any source. These measures aim to minimize to the fullest possible extent the release of toxic, harmful or noxious substances.

Furthermore, part XII includes detailed provisions on land-based sources of pollution, pollution from vessels, seabed activities, dumping, and pollution from or through the atmosphere.

The other central global governance mechanisms relevant to marine pollution include the target 14.1 under the UN Sustainable Development Goals (SDGs) 14： *By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.*

The UN Environment Assembly (UNEA) has adopted several resolutions that relate to marine pollution[4].

International Maritime Organization (IMO) and the International Convention for the Prevention of Pollution from Ships also provide stipulations for marine pollution from the shipping industry.

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) was adopted in 1995. The Program is currently under review but its mandate focuses on marine pollution in relation to three sources: nutrient, litter, and wastewater. Details of these framework at global levels can be found in the Annex.

6.1.2 Emerging global concepts for tackling marine pollution

Many concepts for ocean governance have emerged and been accepted at global or regional levels, notably, blue economy, circular economy, and the source to sea approach.

a. Blue economy

The concept of 'Sustainable Blue Economy' provides a useful approach to examine and address the relationship between ocean-based economic activity and the impact of a changing marine environment. The key opportunity is ensuring that economic activities in the ocean are undertaken without undermining the very ecological assets from which ocean wealth is derived. To further enhance an effective and comprehensive ocean and coastal management, there is a need for each actor to define their role in the ocean space. Other than President XI Jinping's reiteration of the concept of blue economy, some of the progress in this regard are:

[4] General Assembly Resolution 71/312: Our ocean, our future; United Nations Environment Assembly resolution 2.12 on Sustainable coral reefs management; UNEA resolution 2/11 Combating marine plastic litter and microplastics, an assessment of the effectiveness of relevant international, and resolution 3/7, on marine litter and microplastics, resolution 4/L7 on marine plastic litter and microplastics and resolution, 4/L12 on protection of the marine environment from land-based activities.

- The Kenya government held the first sustainable blue economy conference in Nairobi from 26 to 28 November 2018, attracting 18,000 participants from 184 countries around the world.
- A group of Heads of State and government have created a High-Level Panel for a Sustainable Ocean Economy （IISD， 2018）to “catalyse bold, pragmatic solutions for the ocean”.
- In September 2018, the World Bank announced the creation of ‘PROBLUE’ a multi-donor trust fund to support SDG14, addressing marine pollution, overfishing, coastal erosion and sustainable growth of coastal economies.
- The UN Global Compact’s “Action Platform for Sustainable Ocean Business” (UN Global Compact) includes 35 of the world’s largest companies, banks and investment funds, all of whom are leaders in the sectors in which they operate.

b. Circular economy

Targeting marine pollution needs to be done from both an upstream and downstream approach. Focusing on the upstream approach, incudes stopping pollution at its source. As more and more governments are taking action on marine litter and single-use plastic, the concept of “circular economy” has gained increasing attention. The approach aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources, and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital. It is based on three principles: Design out waste and pollution; Keep products and materials in use; Regenerate natural systems. (Ellen Macarthur Foundation)

The European Commission adopted a new set of measures in January 2018 as part of its effort to transform Europe’s economy into a more sustainable one. Hence EU took action to implement a Circular Economy Action Plan. The measures include EU Strategy for plastics in the Circular Economy, options to address the interface between chemical, product and waste legislation, a monitoring framework on progress towards a circular economy and a report on critical raw materials and the circular economy (European Commission, circular economy).

c. Source to Sea approach

A “Source to Sea Approach” will be crucial to addressing land-based activities and pollution. The concept links the land-based with the marine and coastal pollution. Several factors that can affect ecosystems downstream, in the coastal zones and in marine environments, originate from upstream developments on land and along rivers. These include direct sources from production on land such as agriculture, industrial activities, forestry and energy production and through indirect sources such as consumption. In addition, there are several pressures at sea derived from fisheries, transports, extraction of non-living-resources (mining, sand, oil and gas) that affect the marine environment. It may also have effects on coastal zones and upstream in deltas and rivers.

The above challenges, together with climate change and increasing needs of water, food and energy, call for new forms of holistic and integrated management approaches that take the whole continuum from source to sea into consideration. Policies and management systems need to allocate water between sectors and downstream/upstream users, secure reliable delivery and adequate water quality, and protect people and the environment from hazards and degradation of ecosystems. Hence integrating complex economic, social and environmental aspects and dimensions with a source to sea approach is a necessity to achieve sustainable development (Swedish Agency for Marine and Water Management).

6.1.3 Global actions targeting different types of pollutants

a. Nutrients

There are great varieties of nutrient used globally. In some places there is an excessive use of nutrients, and in other regions, there is insufficient use. The main point is that the efficiency of nutrient use is very low on a global scale (Krushelnytska, 2018). Livestock manure is one of the major contributors to nutrient pollution. The United States has a zero-discharge system, if applied properly, treating manure can result in zero nutrient emissions into surrounding freshwater systems (ibid, 2018). As China is among the world's largest producers and consumers of beef, mutton and dairy, and due to the lack of systematic nutrient management planning, most manure generated by large operations is released to the environment without treatment.

A project titled "the GEF-Global foundations for reducing nutrient enrichment and oxygen depletion from land-based pollution", in support of Global Nutrient Cycle, has contributed to the development and application of global-level quantitative modelling approaches, to estimate and map present day contributions of different watershed-based nutrient sources to coastal nutrient loading and their effects, to estimate the magnitude of impact of further nutrient loading on coastal systems under a range of scenarios.

b. Wastewater

Wastewater, both treated and untreated, is widely recognized as a resource. On average, high-income countries treat about 70% of the wastewater they generate, but globally, over 80% of all wastewater (over 95% in some developing countries) is discharged without treatment.

The **Global Wastewater Initiative** is a voluntary multi-stakeholder partnership working to address wastewater-related issues, prompt coordination and encourage investments in wastewater management.

Through the Global Coral Reef Partnership and the Global Wastewater Initiative, a Policy Brief titled "Wastewater Pollution on Coral Reefs", with focus on the impact of wastewater on coral reefs to support the health and resilience of coral reefs has recently been developed.

Moreover, UN Environment and The Regional Organization for the Conservation of the Environment of the Red Sea & Gulf of Aden (PERSGA), one of the Regional Seas Programmes, developed a Manual for Monitoring Indicators of the Impact of Wastewater Discharge on Coral Reefs with the goal of collecting objective information on the value of coral reefs to provide evidence for advocacy of action leading to more effective management. It is also organizing a series of webinars, the overall objective of which is to enhance the understanding and recognition of wastewater as a resource as well as to expand knowledge generation, awareness raising and outreach on crucial issues related to sustainable wastewater management.

The Guidelines on Municipal Wastewater management propose sustainable wastewater management, and ten key mechanisms were pointed out, including securing domestic financial resources, developing integrated urban water supply and sanitation managing systems also addressing environmental impacts, adopting a long-term perspective and taking action step-by-step, and selecting appropriate technology for efficient and cost-effective use of water resources and consider ecological sanitation alternatives.

c. Marine Litter

Today, nothing has captured public in the way that plastic pollution has done. It is therefore unsurprising that many initiatives to address the problem have been launched to address it. The main mechanism that captures the interest of public and government officials are campaigns and various outreach activities to raise awareness. This have laid the foundation to build up a global momentum and encourage various stakeholders to take action on their own:

- Global Partnership on Marine Litter (under UN Environment)
- UN Environment´s Clean Seas campaign
- Charlevoix Ocean Plastics Charter (G7, 2018)
- G7 Marine Plastic Litter Innovation Challenge (G7, 2018, Marine Litter)
- Commonwealth Blue Charter Action Group on Marine Plastics (also known as ‘Commonwealth Clean Oceans Alliance’)
- Communities of Ocean Action, implementation of SDG14.1 (marine pollution)(UN SDG knowledge platform)
- Ad Hoc Open-Ended Expert Group on Marine Litter

The following additional initiatives have a broader scope than marine litter and consider the need for a circular economy approach to plastics, they are worth mentioning here as they provide a key solution to marine litter:

- Global Plastics Platform (European Union and UN Environment)
- The New Plastics Economy Global Commitment (IISD, Plastics Economy)
- European Strategy for Plastics in a Circular Economy (EU Plastics Strategy)

Working in partnership with key stakeholders to drive the action on pollution, support member states to take concrete action will be crucial to be able to address the urgency of the issue.

In accordance with UNEA resolution 3/7, on marine litter and microplastics, the first meeting of the ad hoc open-ended expert group was convened in May 2018, three options were proposed:

1) maintain the status quo and continue current efforts,
2) revise existing frameworks to better address marine plastic litter and microplastics,
3) develop a new international architecture with a multi-layered governance approach.

Due to the failure of the current fragmented and uncoordinated regime to combat marine plastic litter and microplastics, the focus has been on options of a revised and strengthened framework (option 2) or a new framework (option 3).

The second ad-hoc meeting was held in December, the outcome of the discussions among government experts are:

- the need for a holistic and evidence-based approach for circular management of plastic,
- prevention as the priority, and the usefulness of exploring the potential of existing framework (Multilateral Agreements)
- need for strengthened science-policy interface and a source to sea approach,
- extended producer responsibility,

- information exchange,
- circular economy and full life-cycle approach,
- consider the possibility of a global legally binding instrument,
- setting up interim coordinating structure were also discussed at the meeting.

A resolution on marine litter was adopted at the fourth UNEA held in March 2019, in addition, the national source inventory and monitoring methodologies are being developed for marine litter.

In February of 2017, UN Environment's ambitious Clean Seas campaign was launched. Through the campaign, they are driving forward a global movement to take an active role in reducing ocean bound plastic pollution. To do so, Clean Seas connects individuals, civil society groups, industry and governments to transform habits, practices, standards and policies around the globe to dramatically reduce marine litter and the harm it causes. By December 2018, 54 countries have committed to the campaign.

A systemic approach to address marine plastics requires a fundamental system shift from a linear plastics economy to a circular economy by taking actions across the whole value chain, at the design, production, consumption, waste management, as well as mitigation phases. There have been such initiatives focusing on solutions across the whole life cycle of plastics, with the objective of reaching a circular plastics economy. The **Global Plastics Platform,** launched by UN Environment with the European Commission and other governments, is a partnership between UN Environment, national governments and regional organizations. It aims to facilitate dialogue and exchange among governments at the highest level, on their experiences, successes and lessons learned in addressing plastics pollution through a sustainable consumption and production approach. The work of the Global Plastics Platform is organized in five streams: (1) policy, around which the other streams are articulated; (2) circularity, innovation and technologies, (3) education and advocacy, (4) finance, and (5) research. All stakeholders can be involved through these five streams. These streams build on the extensive experience of UN Environment in the area of sustainable consumption and production, e.g. the GEF-Funded project "Addressing Marine Plastics. A systemic approach" and its reports (GEF Marine Plastics publications). The activities of the platform contribute to ongoing discussions among G20 countries on marine litter and resource efficiency. The **New Plastics Economy Global Commitment,** led by Ellen MacArthur Foundation in collaboration with UN Environment), unites businesses, governments, and other organisations sharing the common vision of a circular economy for plastics and targets to address plastic pollution at its source. As of March 2019, over 350 institutions (New Plastics Economy Global Commitment) have signed the New Plastics Economy Global Commitment, including 16 governments from around the world, more than 150 businesses of the plastic packaging value chain (jointly representing over 20% of all plastic packaging used globally), and 26 financial institutions with a combined USD 4.2 trillion worth of assets under management.

d. Antibiotics

Antibiotics and pharmaceutical residues in general in the oceans are causing concern as the full impact for the marine environment is still unknown, it is a new emerging area with much work to be done at both national and regional levels. So far, the Baltic Region has made more progress on that topic.

In the Baltic Sea region, a Pharma platform has been initiated in November 2017, it brings together projects and stakeholders from the whole regional to assist knowledge-sharing, increase effectiveness, streamlining activities and support regional policy development. It will mainly focus on non-regulatory solutions, such as new technical and management options, and encompass three inter-linked columns: projects, supporting activities such as extended stakeholder networks and regional status reports, and policy development (Swedish EPA，2017).

6.1.4 Regional Seas Programmes

More than 143 countries have joined 18 Regional Seas Conventions and Action Plans for the sustainable management and use of the marine and coastal environment. In most cases, the Action Plan is underpinned by a strong legal framework in the form of a regional Convention and associated Protocols on specific problems.

The Regional Seas Framework provides an ideal setting for:

- Applying ecosystem-based management approaches towards governance of our common ocean;
- Ensuring regional strategies are designed to implement and enhance conservation and sustainable use (the blue economy).
- Developing innovative partnerships or governance mechanisms to realize sustainable regional blue economies; and
- Developing regional strategies for ocean governance, based on the sustainable blue economy principles and existing framework(s).

6.2 *National measures*

6.2.1 Examples of national measures

Realising the negative impact of marine pollution, countries all over the world have taken action to curb marine pollution, some examples:

Singapore utilises both legislative controls and administrative measures to control marine pollution from land-based sources. For example, the National Environment Agency (NEA) administers the Environmental Protection and Management Act (EPMA), which provides for the protection and management of the environment through controlling the discharge of trade effluent, oil, chemical, sewage or other polluting matters into the environment. The EPMA also ensures proper management of hazardous substances in an environmentally sound manner. Another example is the control of soil pollution, since pollutants in the soil are likely to make their way into the water system as run-off or groundwater. Other upstream controls implemented by NEA include (i) integrated solid waste management system; and (ii) anti-littering as well as waterways clean-up measures ensuring that land-based litter, including plastic waste, that might otherwise wash into the ocean is prevented from doing so.

NEA also works with partners from the People, Private and Public (3P) sectors on initiatives that contribute to reduce the generation of land-based solid waste, such as the Singapore Packaging Agreement. This voluntary Agreement is an initiative undertaken by the government, industry and non-governmental organisations, to reduce packaging waste.

South Africa has set up a permanent Oceans Economy Ministerial Management Committee which reports to the Vice-President and coordinates with ocean-related departments, so that more effective cross-sectoral ocean governance can be achieved.

The **Kenyan** government organized the first Sustainable Blue Economy Conference from 26 to 28 November 2018. Over 18,000 participants from around the world are coming together to learn how to build a blue economy that: Harnesses the potential of our oceans, seas, lakes and rivers to improve the lives of all, particularly people in developing states, women, youth and Indigenous peoples, and leverages the latest innovations, scientific advances and best practices to build prosperity while conserving our waters for future generations.

In **Sweden**, the 2020 interim targets of the protection of land, freshwater and marine areas include at least 20% of Sweden's land and fresh water areas and 10% of Sweden's marine areas by 2020. This will be achieved through protection or other conservation measures in areas of particular importance for biodiversity and ecosystem services. The formal protection of lakes and rivers will be increased by at least 12 000 hectares and the formal protection of marine areas will be increased by at least 570 000 hectares. Through the development and strengthening of green infrastructure, the ecological relationships are strengthened so that sheltered and preserved areas and habitats are connected and integrated into the landscape, including the marine environment (RAMSAR Convention, National report). The EU Marine Strategy Framework Directive is being implemented in Sweden. The directive was transposed into Swedish legislation through the Marine Environmental Regulation in 2010.

Canada has an Oceans Strategy is the Government of Canada's policy statement for the management of estuarine coastal and marine ecosystems. It commits to promoting institutional governance mechanisms, implementing integrated management planning to engage partners in the planning and managing of ocean activities and promoting stewardship and public awareness (Canada's Oceans Strategy).

6.2.2 Ban and other policies on plastics

The State of Plastics released for 2018 world environment day looked at measures on plastics, including levies, voluntary agreements, total bans, and combined bans and levies, in this report UN Environment has drawn up a 10-step roadmap for governments to follow should they seek to adopt similar measures or improve on current ones. Governments need to curb the amount of plastic waste dumped into the environment and create an incentive to promote the use of bags, enforcement of regulation needs to be strengthened, and alternatives be promoted. As of July 2018, one hundred and twenty-seven out of 192 countries have adopted some form of legislation to regulate plastic bags (UNEP, 2018, Single-Use Plastics). Special measures have been taken by countries have made a direct impact on actions against marine pollution.

The **European Parliament** has approved a ban on single-use plastics such as straws, plates, cutlery and cotton-swab sticks in Europe by 2021. The use of other plastics such as single-use burger and sandwich boxes that do not have practical alternatives at this point will be reduced by at least 25 percent by 2025, and 90 percent of beverage bottles will be recycled, under the proposal.

The **United Kingdom** has implemented a surcharge for getting plastic bags while shopping, while Kenya has gone so far as to punish plastic bag users with penalties up to a $40,000 fine or a four-year jail sentence.

Indonesia plans on reducing plastic litter 70% by 2025.

Uruguay announced it will initiate a tax on single-use plastic bags later in 2018.

Costa Rica will make efforts to reduce plastic waste by increasing proper waste management measures (legislation) and education.

6.3 *Summary*

Several challenges are facing global oceans: inadequate knowledge; ineffective sector/cross-sector policies, cooperation and governance systems; inadequate solutions and incentives to enable and encourage resource efficiency and circular economy approaches; and insufficient public and private financing. Multiple global legal and institutional framework for ocean governance exist but is fragmented, and mostly sector-specific. To achieve integrated ocean governance, some concepts such as Blue Economy, Circular Economy, and Source to Sea Approach, are emerging and applied by countries.

Actions have been taken at the global level to target marine pollution such as nutrients, wastewater, marine litter and antibiotics. It is worth noting that two sessions of Ad Hoc Open-Ended Expert Group on Marine Litter and Microplastics have been held, and it was decided that the process will continue at the fourth UNEA; under UNCLOS, the Intergovernmental Conference on Marine Biodiversity of Areas Beyond National Jurisdiction is underway to discuss a possible third Implementing Agreement under UNCLOS. Initiatives aiming to promote a circular economy for plastics at global level such as the Global Plastics Platform and the New Plastics Economy Global Commitment, will also contribute to addressing marine plastic pollution from its root. At the regional level, the Regional Seas Programmes are playing key roles to curb marine pollution; and mandated by the African Ministerial Conference on the Environment, an African Ocean Governance Strategy is under development. At national levels, initiatives are taken to tackle marine pollution, including marine plastics. Marine pollution and Ocean governance are now high on the agenda at global, regional and national levels.

7. Policy Recommendations

The agricultural and industrial achievements of the past two centuries in feeding, clothing and housing the world’s population have come with the price of seriously degrading important parts of the planet, including much of the marine environment, especially near the coast. Often, while production and emission to a large degree is land-based, the marine environment is in fact the end recipient. In addition to the well-known eutrophication effects from terrestrial nutrient input, the globally growing plastic pollution challenge is another prime example of such interactions.

That is the same case in China. In the 40 years following the Chinese economic reform and opening policy, China has formed a coastal ribbon of high economic development, which has brought with it population density and urbanization. Coastal and marine ecosystems are subject to tremendous ecological damage and land-based pollution pressures while supporting coastal economic development. The ability to sustain development has declined significantly. More than 70% of nutrients discharged into the sea are from land-based origins, and these and other sources of pollution being leached into the marine environment have led directly to a decline in marine water, sediment and biological quality. Beyond the obvious direct link to marine water quality, the volume of pollutants discharged into the sea has a direct connection to huge economic costs tied to marine fisheries, marine tourism, and human health and safety. Marine pollution also causes environmental degradation, the decline in biological diversity, and the loss of ecosystem services, each of which may be difficult to account for in monetary terms but is significant nonetheless.

Recently, China has made full use of the substantial foundation accumulated over the past 40 years of economic reform, and step up efforts to promote ecological civilization construction. Pollution control is one of the three tough battles which Chinese government must win. At present, the China's environmental quality has been going to improve. In order to further pursue a path of harmony between people and the ocean, promote conservation and green development of the oceans, enhancing ocean-based prosperity, the policy recommendations are proposed to address marine pollution control and prevention.

I. Establishing a holistic mechanism of land-sea coordination in joint marine pollution prevention and control

Significantly enhance the land-sea ecological environment monitoring unity. In accordance with the principle of land-sea coordination and the unified plans, optimize the construction of a fully covered and refined marine ecological environment monitoring network, strengthen gridded and real-time monitoring, and develop the online monitoring for the primary rivers and outlets discharging and atmospheric deposition of pollutants into the sea. Establish a baseline survey/census system for marine pollution.

Enhance management and prevent land-based pollution from the agricultural, pharmaceutical sectors. Full consideration should be given to improving overall agricultural production capacity and to preventing and controlling rural pollution. Development of environmental protection facilities, such as those for handling rural wastewater and refuse, should be bolstered by subsidies from governments and village collectives, fee payments from residents, and the participation of non-government capital. A variety of assistive measures should be adopted to foster and develop market entities for the control of all types of agricultural pollution from non-point sources and for the handling of rural wastewater and refuse. Green production way in agriculture should be pursed to promote making full use of agricultural wastes. According to the market-based rules, a green finance system is encouraged to support the pilot of disposal and harmless treatment of livestock and poultry breeding. Comprehensive utilization of livestock and poultry manure might be gradually achieved on the spot. Subsidies for the production of organic fertilizers from the comprehensive utilization of livestock and poultry manure need to be increased, and simultaneously subsidies for chemical fertilizer to be reduced. The management of antibacterial drugs used for human and animals should be strengthened. Proper procedures should be introduced to restrict the use of chemicals such as antibiotics in accordance with the law, and prohibit the abuse of antibiotics.

Further improve China's marine environmental quality target system. China's marine environmental quality target system is mainly based on water quality targets, which are often expressed by the under-criteria rate of marine functional zoning or clean water (below the criteria of grade I, II). Suggest to further enrich the content of China's marine environmental quality target system, in addition to the water quality target, the spatial and temporal distribution characteristics of marine ecosystems need to be combined, further increase marine ecological protection target, such as the biodiversity, habitat suitability, ecosystem structure and function, etc., lay the foundation and direction for the marine ecological protection work. Strengthen the connection of sorting, indices selecting, and valuing of water quality standards between surface water and seawater, and introduce new indices such as total phosphorus, total nitrogen, and emerging pollutants. Advance seawater quality standards revision. Take a holistic approach for emissions control and water quality target management in the river basins and offshore areas.

Construct an integrated governance mechanism for the River Chief and Bay (Beach) Chief systems. In accordance with the holistic approach to conserving our mountains, rivers, forests, farmlands, lakes, and grasslands, strengthen coordination of the comprehensive management of rivers discharging into sea, bay and estuarine. Establish a joint-action mechanism between the River Chief System and Bay Chief System, set a regular consultation mechanism and emergency response mechanism, and enhance the capability of pollution prevention and control in a holistic approach for land and sea.

II. Strength lifecycle management for plastics, and formulates a national action plan for marine debris pollution prevention and control

Strengthen the source control of plastics debris. Explore the waste reduction and harmless management pattern in line with national conditions, and effectively prevent the entry into marine environment of microplastics and plastic waste resulting from the manufacturing production and individual consumption process, severe weather events and natural disasters in coastal regions. Strengthen the management of plastic nurdle, and put on file and supervise of the process of "resin nurdles - plastic products – usage and circulating of commodity". Encourage extended producer responsibility (EPR) and related mechanisms. Promote EPR mechanisms to involve producers, importers and retailers in the establishment of resource-efficient product value chains from the design to the end-of-life treatment and in financing waste collection and treatment. Forbid to produce and sell personal care products containing plastic micro-beads. Introduce technologies in washing machines to better capture fibres from wash-loads in both domestic and commercial/industrial uses.

Support integrated sustainable waste management. Improve and developing national waste regulatory frameworks, including legal framework for EPR, and taking care for enforcement and governance. Support capacity development and infrastructure investments for improved waste management systems in cities and rural areas through existing instruments, and promote access to regular waste collection services and facilitate investments in waste management infrastructure in order to prevent plastic waste leakage into the sea. Establish sufficient waste reception facilities at harbors in coastal cities in order to allow ships to dispose of their waste in an environmentally sound manner.

Formulate a national action plan for marine debris pollution prevention and control. Promote the establishment of sound national regulatory frameworks on waste management. Construct an integrated coordination mechanism for marine debris prevention and control across sectors, regions and river basins. Encourage green development, speed up the research and application of innovative approach for substitute for plastic products and waste treatment, and urge the manufacturing and use of degradable plastic products and substitutes for plastic. Strengthen researches on sources, transport and fate of microplastics as well as the impact on marine ecological environment, and improve the scientific understanding of microplastics. Call on all relevant stakeholders to engage and encourage social organizations, communities and the public to reduce plastic waste generation, hold clean-up activities, significantly reduce the unnecessary use of single-use plastics, and live green-consumption lifestyle, with the aim to prevent and significantly reduce marine microplastic pollution.

III. Develop a market system which allows economic levers to play a greater role in marine environmental governance and ecological conservation

Accelerate industrial innovative and green development and transformation in coastal areas. Promote industrial upgrading toward to emerging industries and modern service industries. Strengthen the construction of industrial zones, promote circular economy and green production, build ecological industrial zones, and enhance the integrated and recycling utilization of resources. Set the binding requirements including industrial structure and layout, resource and environmental capacity loads, and ecological red lines. Strengthen the management of project approval, enhance the market entry, compel industrial transformation and upgrading, and progressively fall into disuse lagged behind production capacity.

Improve the system for compensating marine ecology conservation efforts. Persist to the principle of "who benefits, who compensates", comprehensively use fiscal, taxation and market measures, adopt the form of incentive instead of subsidies, and establish a compensation mechanism for marine ecological conservation.

Strictly implement compensation systems for ecological and environmental damage.

Tighten manufacturers' legal responsibilities for environmental protection, and significantly increase the cost of illegal activities. Improve legal provisions concerning marine environmental damage compensation, methods for appraising damage, and mechanisms for enforcing compensation. In accordance with the law, mete out penalties to those who violate environmental laws and regulations, determine compensation for ecological and environmental damage by the extent of damage and other factors, and pursue criminal liability when violations result in serious adverse consequences.

Establish a diversified funding mechanism. Integrate various types of marine environmental protection funds by central budget, increase financial support, and keep supporting the rural environmental governance and Blue Bay restoration actions. Bring into full play the initiative of local budget, enhance local financial support, make full use of market investment and financing mechanisms, and encourage and attract private, social, venture capital and other funds to gather in the area of marine environment protection.

IV. Strengthen protection and remediation of coastal wetlands, and restore the ecological functions of wetlands including water purification

Improve coastal wetland grading management system. Establish important coastal wetlands grading management systems at national and local levels, release in batches the national important coastal wetlands list, and identify the control proportion target of coastal wetlands at local level. Innovate the protection pattern, and establish the coastal wetland pilot national park.

Establish degraded coastal wetlands restoration system. In accordance with the natural attributes of marine ecosystems and the characteristics of coastal biota, carry out the coastal wetland restoration. Implement the restoration projects, including restoring the coastal aquaculture farms back to wetlands, culturing densely vegetation, conserving habitat, improve the community structure of wetland vegetation, and raise the biodiversity of wetland habitats. Expand the coastal wetland area and recover the ecological services of wetland, such as water purification, carbon sequestration. By 2020, the restored area of coastal wetland will be more than 20,000 hectares.

V. Strengthen cooperation and exchanges, and jointly address global marine pollution

Strengthen research on emerging marine environmental issues of global concerns. Conduct survey and research on ocean acidification, plastics and microplastics, oxygen deficiency in hotspot areas, and comprehensively analyze the emerging marine environment issues of global concerns, particularly in the high seas and Polar Regions. Deeply participate in the designation of high seas protected areas, environmental impacts assessment of seabed development activities, and research on marine environmental protection in Polar Regions, and play our part in global marine environmental governance.

Establish Maritime Community with a Shared Future to jointly address marine pollution. With the aid of the 21st Century Maritime Silk Road, carry out pragmatic and efficient cooperation and exchange under the framework of the Asian Infrastructure Investment Bank, China-Pacific Island Economic Development Cooperation Forum, China-ASEAN Maritime Cooperation, and Global Blue Economy Partnership Forum etc. Strengthen research on marine environmental issues of global concerns, build a broad blue partnership, jointly improve the ability to address and control marine pollution. Establish China-ASEAN Marine Environmental Protection Cooperation Mechanism, and promote international cooperation. Enhance capacity on pollution monitoring and governance through sharing knowledge making best use of other relevant efforts in the region such as PEMSEA, APEC, NOWPAP and COBSEA, GPML, GPNM, GWI and work together to build a community of shared future for mankind.

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