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## Study on compliance assessment of ship exhaust emissions in China's ECA (Emission Control Area)

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**WORLD MARITIME UNIVERSITY**

Dalian, China

**STUDY ON COMPLIANCE ASSESSMENT OF  
SHIP EXHAUST EMISSIONS IN CHINA'S ECA  
(EMISSION CONTROL AREA)**

By

**HU YAHAN**

**The People's Republic of China**

A dissertation submitted to the World Maritime University in partial  
Fulfillment of the requirements for the award of the degree of

**MASTER OF SCIENCE**

**In**

**Maritime Safety Environmental Management**

**2019**

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## **DECLARATION**

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

**Supervised by: DR. DONG CHENG**

**Professor of Dalian Maritime University**

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Thanks to my family for their encouragement and support. I am very grateful for their help to me so that I can successfully complete the thesis.

Finally, thanks to my classmates for the wonderful time together.

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## ABSTRACT

Title of Dissertation:     **Study on Compliance Assessment of Ship Exhaust Emissions in China's ECA (Emission Control Area)**

Degree:                             **MSc**

With the worldwide concern for the environment, the air pollution of ships has gradually caught the attention of the international organizations and governments. The relevant policies and regulations have been promulgated and improved, and some emission control areas have been established. In order to prevent and control ship air pollution, China has also issued corresponding policies and established emission control areas.

This paper mainly introduces the current situation of emission control areas in China, the corresponding policies and some current technical means. Through the investigation, it is found that China's emission control areas still need to be further improved; at the same time, technical support is needed, for example, related technologies for controlling ship's exhaust emissions, and related detection technologies for helping relevant departments to supervise the exhaust emissions need to be upgraded and developed; and related implementation schemes and control requirements need to be updated.

**KEY WORDS:** ECA, SO<sub>x</sub>, NO<sub>x</sub>, China, ship exhaust emissions

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## LIST OF ABBREVIATIONS

APPCAP	The Action Plan for the Prevention and Control of Atmospheric Pollution
CCS	China Classification Society
CNOOC	China National Offshore Oil Corporation
DOAS	Differential Optical Absorption Spectroscopy
DIAL	Differential Absorption Laser Radar Technology
ECA	Emission Control Area
FTIR	Fourier Transform Infrared Spectroscopy
IMO	International Maritime Organization
LNG	Liquefied Natural Gas
LIF	Laser Induced Fluorescence
MEPC	Marine Environment Protection Committee
MARPOL	International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978
NDIR	Nondispersive Infrared
NDUV	Nondispersive Ultraviolet
NECA	NO <sub>x</sub> emission control area
PSC	Port State Control
R & D	Research and Development
SCR	Selective catalytic reduction
SECA	SO <sub>x</sub> emission control area
UNCLOS	United Nations Convention on the Law of the Sea

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Background information

Environmental issues have attracted worldwide attention. Although water transport is relatively friendly to environment, shipping accounts for a large proportion of global trade. Kim (2015) said that almost 90% of trade and transportation are completed by sea, and the environmental pollution caused by it cannot be underestimated. The International Maritime Organization (IMO) has always attached great importance to the issue of atmospheric pollution from ships. In 1997, it adopted the 1997 Protocol to MARPOL73/78 Convention and decided to add a new Annex VI to MARPOL73/78 Convention, the International Rules for the Prevention of Air Pollution Caused by Ships, which limits the contents of sulfur oxides (SO<sub>x</sub>) and nitrogen oxides (NO<sub>x</sub>) in ship exhaust gas and sets emission control areas. Annex VI to MARPOL came into force on 19 May 2005. In April 2008, the IMO Marine Environmental Protection Committee (MEPC) agreed to step up the implementation of SO<sub>x</sub> and NO<sub>x</sub> emission limitation requirements, and the revised VI clause of MARPOL73/78 came into force on July 1, 2010. Annex VI of MARPOL 73/78 specifies the limitation requirements for the emission of NO<sub>x</sub>, SO<sub>x</sub> and particulate matter from ship exhaust emissions, stipulates fuel sulfur content standards, diesel engine NO<sub>x</sub> emission standards and a clear implementation schedule. Among them, SO<sub>x</sub> emission control area is called SECA, NO<sub>x</sub> emission control area is called NECA, collectively referred to as ECAs.

On the basis of the MARPOL Convention, the IMO voted in February 2012 to adopt a proposal to reduce the emissions of particulate sulphide from marine vessels. In the same period, the IMO agreed to reduce the upper limit of applicable standards for sulphur content in marine fuel from the current 1% to 0.1% in the European Emission

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Control Area (ECA) starting in 2015. In all European waters except ECA, the upper limit of applicable standards for sulfur content in ship fuel will be reduced to 0.5%, and further to 0.1% by 2020, and the applicable standards for sulfur content of 0.1% will be extended to 12 nautical miles of territorial waters of all member countries. IMO stipulates that all ships operated in ECA by ship operators in 2015 must install exhaust gas cleaning systems or switch to low-sulfur fuel. By 2020 or 2025, the 0.5% sulfur cap will be in effect worldwide.

At the MEPC 70 meeting held in London on October 26, 2016, a resolution was adopted that the sulfur content of ship fuel should not exceed 0.5% in the global sea area from January 1, 2020. On July 3, 2017, MEPC 71st meeting reconfirmed that on January 1, 2020, the implementation date of the 0.5% m/m fuel content standard in the global sea area remained unchanged, and the 0.1% m/m fuel sulfur content standard was still implemented in the emission control area (Zhou, 2018). Annex VI of MARPOL73/78 Convention "Rules for the Prevention of Atmospheric Pollution from Ships" (abbreviated as Annex VI) requires that the sulfur content of marine fuel be less than 4.5% in general area (hereinafter referred to as high sulfur fuel) and less than 1.5% in sulfur oxide emission control area (SECA) (hereinafter referred to as low sulfur fuel).

China also attaches great importance to environmental issues. Waterway transportation is an important part of China's transportation system. The pollution of ships and ports will have a great impact on the water environment and the land environment of surrounding ports, which is closely related to public interests. Zhou (2018) believes that strengthening pollution prevention and control of ship ports is not only the inherent requirement of the development of transportation industry itself, but also a positive response to the increasing public demand for ecological environment.

In recent years, the State Council has issued the Action Plan for the Prevention and Control of Atmospheric Pollution (hereinafter referred to as "APPCAP") and the

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Opinions of the State Council of the Central Committee of the Communist Party of China on Accelerating the Construction of Ecological Civilization (hereinafter referred to as "Opinions on the Construction of Ecological Civilization") and other relevant documents. Among them, "Opinions on the Construction of Ecological Civilization" puts forward the overall requirements of perfecting the system of ecological civilization, and the pattern of land and space development, promoting resource conservation and utilization in an all-round way, the efforts of natural ecosystem and environmental protection, green development, cyclic development and low-carbon development. At the same time, it puts forward the working requirements for green, low-carbon, energy-saving and emission reduction in transportation industry and pollution prevention and control in an all-round way. "APPCAP" put forward "to establish regional joint defense and control mechanism around Bohai Sea, including Beijing, Tianjin, Hebei, Yangtze River Delta, Pearl River Delta, etc. Strengthening the management of PM2.5 in densely populated areas and major cities, and the assessment system of responsibility for the target of atmospheric environmental improvement in various provinces (districts and cities) should be established. "

Gao, et al (2017) expressed that transportation industry is the pioneer of social and economic development, and has been an active practitioner of green and ecological development. In order to implement APPCAP, and promote the development of green shipping and energy saving and emission reduction of ship ports, in 2015, the Ministry of Transport issued a series of policy documents, such as the Action of Preventing and Controlling the Pollution from Ships and Ports (2015-2020) (hereinafter referred to as "the Action Plan") and Implementation Plan on Domestic Emission Control Areas in Waters of the Pearl River Delta, Yangtze River Delta and Bohai Rim (Beijing, Tianjin and Hebei), which are related to pollution prevention and control of ships and ports to be deployed. As a programmatic document, the Action Plan clearly states that the prevention and control of pollution in ships and ports should focus on the prevention and control of air and water pollutants, pollutant

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discharge and disposal, to improve the system of regulations and standards and strengthen the monitoring and supervision of pollutant emissions as a means of ship and port pollution prevention and control work as a whole. In May 2016, the Ministry of Transportation issued the 13th Five-Year Development Plan for Energy Conservation and Environmental Protection of Transportation (hereinafter referred to as the Plan). In the Plan, pollution prevention and control of ports and ships will be one of the key tasks of the Ministry of Transport during the 13th Five-Year Plan period. It is proposed that "the Action Plan" be implemented in an all-round way, and the "Implementation Plan on Domestic Emission Control Areas in Waters of the Pearl River Delta, Yangtze River Delta and Bohai Rim (Beijing, Tianjin and Hebei)" be implemented in stages and steps to promote oil and gas recovery and treatment at crude oil product terminals, special pollution control at port operations, structural adjustment of ships, construction of marine pollutant receiving facilities and application of LNG fuel. In 2017, the Ministry of Transport issued "the Guiding Opinions on Promoting the Development of Green Shipping in the Yangtze River Economic Zone", "the Action Plan for the Prevention and Control of Ship Pollution in the Yangtze River Economic Zone (2018-2020) " and "the Port Coastal Power Layout Scheme", which further contributed to the prevention and control of ship pollution in the Yangtze River Economic Zone, promoted the construction of Port Coastal Power facilities, and controlled the emission of air pollutants from ships.

## **1.2 Objectives of research**

The Eighteenth National Congress of the Communist Party of China took the construction of ecological civilization as a historical task and incorporated it into the overall layout of the "five in one" cause of socialism with Chinese characteristics. The national strategy of ecological civilization has been formulated. It is proposed that we must firmly establish the concept of ecological civilization, adhere to the basic national policy of resource conservation and environmental protection, strive to

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promote green, cyclical and low-carbon development, accelerate the formation of a spatial pattern, industrial structure, mode of production and lifestyle of resource conservation and environmental protection, and reverse the deteriorating trend of the ecological environment from the source (Wang, 2017). The national strategy of ecological civilization is a concentrated reflection of the development thinking, direction and focus of our country in the new period. In 2015, the State Council issued a series of important action programs related to pollution prevention and control work. In the same year, the Ministry of Transport put forward specific work targets for ship and port pollution prevention and control.

China is a world shipping and port country. Data released by the Ministry of Transport (2018), by the end of 2018, China's ports had 23,919 production berths (2,444 berths of 10,000-ton class or above). Among them, the berths for the production of coastal ports are 5,734; the berths for the production of inland ports are 18,185. The national port completed cargo throughput of 14.351 billion tons, completed container throughput of 251 million TEU, and possessed 137,000 ships for water transportation. It is estimated that by 2020, China's international and domestic shipping volume growth rate will be about 4% and 5%, the growth rate of cargo throughput in coastal ports will be about 5%, and the growth rate of inland water transportation will be about 7%. Xu and Han (2016) believe that the vigorous development of waterway transportation has brought tremendous pressure on ship and port pollution prevention. Ship and port pollution prevention and control has always been one of the focuses of the water industry, and is an important part of the industry's green development and an important part of ecological civilization construction. Ship and port pollution control includes ship air pollution control, port pollution prevention and ecological maintenance, terminal oil and gas recovery, ship pollutants receiving and disposal, and clean energy applications such as LNG and shore power.

At present, China's ship and port pollution control work has achieved certain results. At present, dust pollution control measures have been adopted in the upstream and

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downstream ports of coal transportation and major ore transportation ports throughout the country. Some docks are equipped with oil and gas recovery devices and shore power engineering for berthing ships, which effectively reduces pollution emissions from ships and ports (Xu and Han, 2016). However, Ma, et al (2017) believes that the work of pollution prevention and control of ships and ports is still not optimistic, there are still many problems, such as imperfect standards, relatively lagging ship air pollution control, weak industry monitoring and regulatory capacity, and so on. From the point of view of technical support, the key technologies of oil and gas recovery and localization equipment, high efficiency and low cost ship pollutant disposal equipment, ship pollutant monitoring and supervision technology, ship and port operation energy efficiency monitoring technology and related standards have become the technical bottlenecks restricting China's efforts to promote the prevention and control of ship and port pollution.

The establishment of emission control areas in China is one of the important means to prevent and control air pollution from ships. The implementation plan of emission control areas in China cannot be separated from specific policies for control and requirements. It also needs a series of prevention, control and supervision technologies to ensure the smooth implementation of requirements. At the same time, it also needs favorable policies and relevant regulations to ensure the development and use of technologies.

This study summarizes and analyses the implementation of China's emission control areas, evaluates the emission situation and supervision in the control areas, studies and puts forward suggestions on the main direction of air pollution prevention and control technology, the follow-up development of China's emission control areas, the revision of relevant standards and practical technology policies. The research results can help to further develop and improve China's emission control. To promote the development of related industries is of great significance to the establishment of a relatively perfect standard and norm system for pollution prevention and control of

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ships and ports.

The Ministry of Transport has issued relevant policy documents, which set clear goals and specific requirements for the prevention and control of ship air pollution, and played a vital role in promoting the transformation and upgrading of the industry. However, in other areas, such as monitoring and supervision of ship pollution, relevant policies still need to be studied and formulated. In addition, at the implementation level, it is still necessary to study and promulgate relevant supporting policies to support the smooth implementation of relevant policies, so as to achieve the overall development of the industry.

China still has large bottlenecks in key core technologies for ship and port pollution prevention, and there is still a large gap compared with developed countries such as Europe and the United States. For example, in the independent research and development of key technologies, equipment automation, intelligence, complete sets, standardization, security, and market share of domestic equipment with independent intellectual property rights need to be further improved. Through technological independent innovation, facilities and equipment science and technology, we will break through the key technical bottlenecks that restrict China's promotion of pollution prevention in ship ports, promote the transformation and upgrading of the industry, and lead the scientific and standardized development of the industry.

In terms of standard revision and revision, existing regulations and standards still cannot meet the needs of ship and port pollution prevention and control work. For example, there are few regulations and regulations on the prevention and control of inland river pollution, the coverage of existing standards and regulations is not comprehensive enough, some standard technical contents need to be updated, and there is a lack of perfect ship port pollution prevention and control standards system. To a certain extent, the paper can provide ideas for promoting the scientific management of the industry.



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### **1.3 Structure of dissertation and Methodology**

According to the current control requirements and implementation status of China's emission control areas, and the existing problems in China's emission control areas, it is proposed to carry out relevant research from the current ship air pollution control technology, ship and port pollutant monitoring and supervision technology. By analyzing the current situation, development trend and main problems of technology research in the above fields, this paper puts forward the relevant technical framework system and classification as well as the future technological development route, formulates the guiding policy of technology promotion or encouragement application, and perfects the existing technological standard system. At the same time, China's emission control areas will be evaluated and recommendations for follow-up development will be provided.

This study intends to use literature research, expert consultation and departmental research to sort out the current status of China's ship air pollution prevention and control technology, analyze the current suitability of China's ship air pollution control technology and existing major problems, and fully grasp the future development trend of the industry. And the study intends to put forward the development goals of China's ship air pollution prevention and control technology, and clarify the technical framework system and classification. For the cutting-edge technology, it is necessary to propose the next major research direction or technical development route of the technical direction; for the technical direction with good research foundation, propose the standard norm system revision plan, technical development policy and guidance.

## **CHAPTER 2**

### **THE SITUATION OF CHINA'S EMISSION CONTROL AREA**

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## 2.1 Overall implementation of emission control area in China

Since the implementation of the ship emission control zone plan, the Pearl River Delta, the Yangtze River Delta, and the Bohai Sea (Beijing Tianjin Hebei) three areas ship discharge control phase implementation requirements have been implemented in batches, and the overall situation is good. Among them, the four core ports in the Yangtze River Delta Control Zone and Shenzhen Port are the first to test the emissions control requirements for 2017 and 9 months ahead of schedule, and the non-core ports in the Yangtze River Delta will implement the 2018 emission control four months ahead of schedule. The district requirements have played a role in demonstrating and leading. The remaining ports were implemented as scheduled according to the requirements of the plan.

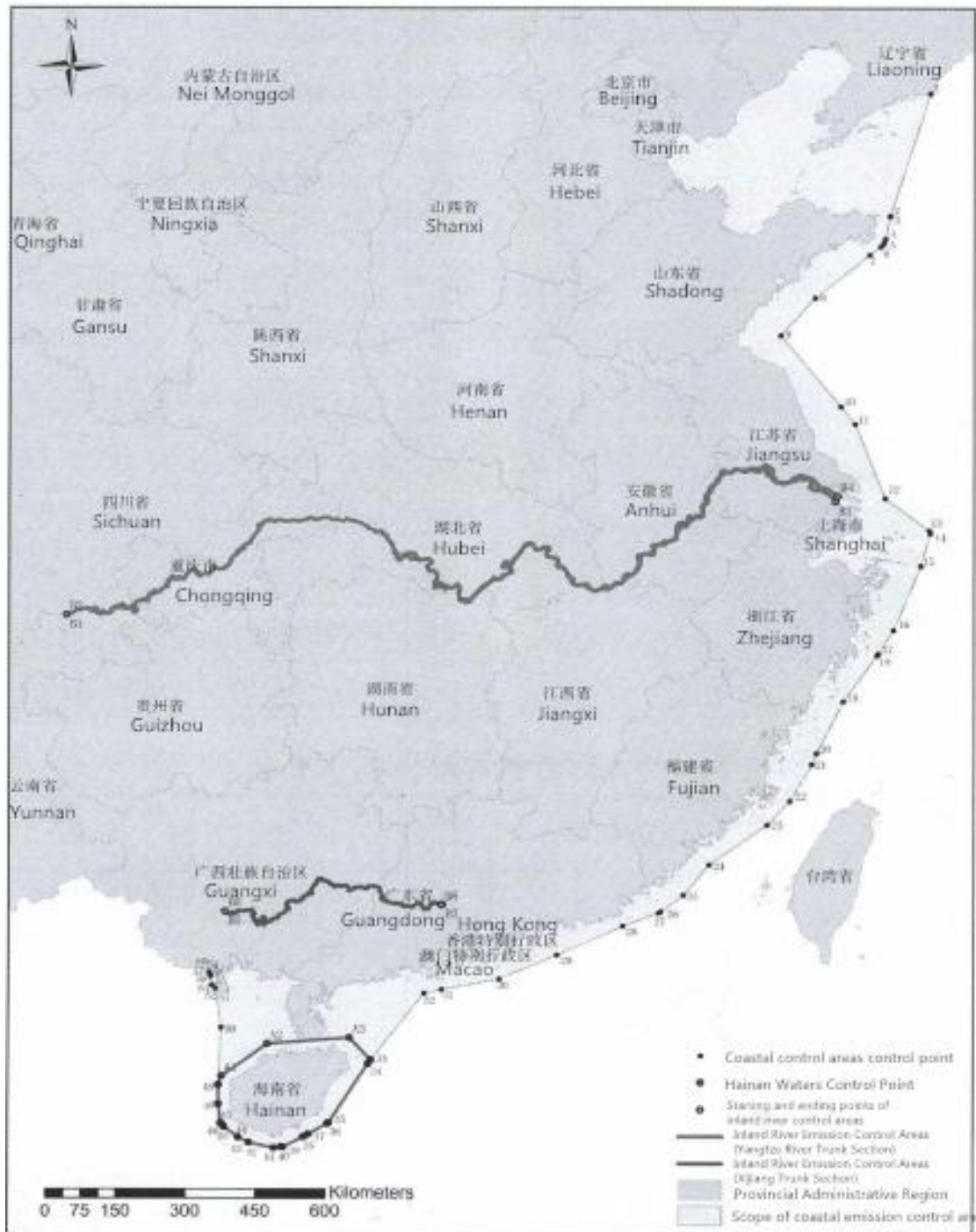
According to Ren (2017), each region actively promotes policy implementation in conjunction with local characteristics. Firstly, the supporting documents were released. All provinces and municipalities have issued relevant supporting documents for the implementation of the control area, further refining the task requirements and clarifying the division of responsibilities. Secondly, incentive policies were implemented. By the end of 2017, Shenzhen had issued a total of about 0.77 billion RMB to reward ships for the use of low-sulfur fuel and shore power; Guangzhou City allocated more than 2.2 million RMB as a special fund for the prevention and control of air pollution in ships; Shanghai, Zhejiang, Jiangsu and Lianyungang cities respectively introduced subsidies for shore power use. Then, regional linkage will be carried out. Provinces and municipalities around the Bohai Sea Control Zone signed the agreement of "Maritime Regulation Cooperative Mechanism of Ship Emission Control Zone around the Bohai Sea (Beijing, Tianjin and Hebei)", one city and two provinces in the Yangtze River Delta established a regional joint defense and control mechanism, and the maritime departments of Guangdong and Shenzhen established a joint law enforcement and supervision mechanism of ship emission control in the Pearl River Delta with the Hong Kong Environment Bureau and the Hong Kong

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Environmental Protection Agency. Finally, the application of equivalent measures should be promoted. At present, more than 1000 sets of port shore power have been built all over the country. Low-voltage shore power is widely used by inland ships. Some large coastal wharfs also have shore power supply capacity. The Ministry of Transport (2017) has counted 135 inland LNG powered ships and 16 inland LNG filling wharfs, but only three of them are carrying out filling operations. Shanghai and Jiangsu are promoting the planning and construction of LNG filling stations and the transformation of LNG powered vessels through relevant policies.

By the end of 2017, the maritime agencies in the emission control area had carried out supervision and inspection of 36,706 ships, of which 6,494 were fire samples, accounting for 17.69% of the total inspections, and 251 administrative penalties were imposed on ships not using compliant fuel. From the fuel sampling inspection of ships, the indirect violations of inland rivers and rivers and seas are the most common. The non-compliance rate is 25.88%. The domestic coastal navigation vessels and international navigation vessels are relatively good. The non-compliance rates are 5.33% and 3.25% respectively.

In November 2018, the Ministry of Transport issued the “Implementation Plan for Marine Air Pollutant Emission Control Areas”, which stipulated the scope of new atmospheric emission control areas, as shown in Figure 2.1-1. The new scheme has guaranteed the fair competition of ports in the region to a certain extent, and at the same time increased the enthusiasm of the port to promote energy conservation and environmental protection.



**Figure 2.1-1 The scope of new atmospheric emission control areas of China**

Source: the “Implementation Plan for Marine Air Pollutant Emission Control Areas”

## 2.2 Environmental benefit assessment of emission control area

In the aspect of ship air pollution, Chang, et al (2017) summarized and analyzed the emission of related pollutants. In 2016, SO<sub>2</sub> emissions from ships in coastal and

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inland waters were about 1.1 million t/a, NO<sub>x</sub> was about 2.29 million t/a, PM10 was about 160,000 t/a, PM2.5 was about 140,000 t/year, accounting for 2%, 4%, 0.6% and 0.7% of the total pollutant emissions in China. About 420,000 tons of SO<sub>2</sub> and 790,000 tons of NO<sub>x</sub> are emitted by ships in the three emission control areas, accounting for 39% and 35% of the national ship emissions respectively; about 142,000 tons of SO<sub>2</sub> and 109,000 tons of NO<sub>x</sub> are emitted by ships in the core port area. In 2015, about 1.2 million tons of SO<sub>2</sub> and 2.2 million tons of NO<sub>x</sub> were discharged from ships in China (200 nautical miles range). They accounted for 3%-7% of the total discharge of various pollutants, and about 300,000 tons of SO<sub>2</sub> and 540,000 tons of NO<sub>x</sub> from ships in the three emission control areas, accounting for about 25% of the total discharge of ships in China.

According to the environmental monitoring data, the air quality of ports with emission control has continued to improve, and sulfur oxides in some ports have decreased significantly.

For example, from April 2016 to the end of 2017 in Shanghai, the average sulfur dioxide concentration decreased by 26.2% compared with the same period, especially near the port area. The sulfur dioxide concentration of Baoshan monitoring station decreased by 30.2% compared with the same period, and that of Gaoqiao monitoring station decreased by 52%. The concentration of sulfur dioxide in the air monitoring sites near the eastern port of Shenzhen decreased by 30% year on year. The daily average sulfur dioxide concentration in Beijing-Tanggang Port within one month after the implementation of the emission control zone policy was 56% lower than before (China Traffic News Network, 2017).

From the estimation results of pollutant emissions, the annual emissions of sulfur oxides from ships in the three emission control areas decreased by 69,000 tons and particulate matter by 0.8 million tons in 2017. According to the requirements of the Program, the sulfur oxides and particulate matter will be reduced by 393,000 tons and

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57,000 tons in 2020 compared with that in 2015, with a decrease of 80% and 75% respectively.

From the estimation results of pollutant emissions, the annual emissions of sulfur oxides from ships in the three emission control areas decreased by 69,000 tons and particulate matter by 0.8 million tons in 2017. According to the requirements, in 2020, there will be a reduction of 393,000 tons of sulfur oxides and 57,000 tons of particulate matter, 80% and 75% respectively, compared with 2015. The Special Action of the Ministry of Transport requires that "by 2020, the sulfur oxides, nitrogen oxides and particulate matter of ships in the Pearl River Delta, Yangtze River Delta and Bohai Sea Rim (Beijing, Tianjin and Hebei) will be reduced by 65%, 20% and 30% respectively compared with 2015". At present, it seems that only the implementation of emission control zone policy can achieve the required sulfur oxide and particulate matter emission reduction targets.

### **2.3 Current status of technologies related to prevention and control of ship air pollution**

To ensure the effective implementation of the relevant requirements of China's emission control areas, technical support is indispensable. From the perspective of exhaust emissions, ships themselves need to have effective technical means to reduce the concentration of emissions. At the same time, as a regulatory authority, it is also essential to use technical means to monitor whether the emissions of ships in the region meet the standards.

#### **2.3.1 Current Situation of Ship Air Pollution Control Technology**

At present, the main control measures of ship air pollution at home and abroad include changing to cleaner marine fuel, using shore power technology at port, clean

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energy power ship technology, ship engine technology improvement and ship speed control. The main control objects include sulfur oxides, nitrogen oxides, particulate matter, and black carbon, which has gradually attracted international attention.

### ***2.3.1.1 Change to cleaner marine fuel***

Guo, et al (2019) shows that switching to cleaner marine fuel is one of the most widely used pollution control methods at home and abroad. It has obvious control effect on sulfur oxides, and has a certain emission reduction effect on particulate matter, black carbon and so on. Ship emission control areas recognized by IMO in Baltic Sea, North Sea, North American Sea and Caribbean Sea, under the framework of U.S. and EU decrees, as well as ship emission control areas around Bohai Sea (Beijing-Tianjin-Hebei), Yangtze River Delta and Pearl River Delta in China, all focus on pollution control measures by switching to low-sulfur fuel.

### ***2.3.1.2 Clean Energy Power Vessel***

Clean energy powered ships can reduce emissions of atmospheric pollutants such as sulfur oxides and particulates in the process of using clean fuels. At present, liquefied natural gas (LNG) is the most widely used marine clean fuel. There are also some electric ships, hydrogen fuel ships, biomass fuel ships, solar power ships and other research and trial applications. Among them, LNG power and electric power are the most promising technologies.

LNG power vessels are mainly based on new sea-going vessels abroad, while a series of technologies for LNG applications in inland vessels and ocean-going vessels have just been researched; Wu and Duan (2017) have stated that engines mainly have single-fuel and micro-ignition engines (Diesel <5%), the technology is more advanced, NO<sub>x</sub> emissions can reach Tier III, but the cost is too high. The construction and

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renovation of LNG power ships in China are developing in a balanced way, but most of them are inland ships. Researches on coastal ships have also been conducted, but the application of LNG fuel in ocean-going ships is just beginning, as in foreign countries. There are mainly two types of engines: single fuel and mixed fuel (diesel-gas ratio is about 7:3). The emission of NO<sub>x</sub> can only reach Tier II, but the cost is much lower than that in foreign countries. Du and Zhang (2015) introduced that the fuel filling of LNG powered ships mainly includes tank car-ship filling, shore station-ship filling, barge-ship filling, ship-ship filling and floating facilities-ship filling at sea. The construction and management standards for barge filling stations have been promulgated, and the construction specifications for mobile filling vessels have also been issued. But safety regulations are still being studied. Research on tank trucks, shore-based filling stations and floating filling at sea has also been carried out. Chen and Yuan (2017) introduced that electric ship technology has made some breakthroughs in recent years. Electric ships have the characteristics of good acceleration performance, fast braking speed and low noise. At present, there are a few applications in China. They are mainly suitable for harbor ships and small tonnage cargo ships. In addition, since August 2018, the Netherlands has launched a number of electric container barges in ports such as Amsterdam, Antwerp and Rotterdam. (Zhou, 2018).

### ***2.3.1.3 Marine engine technology improvement***

Ship engine technology improvements are mainly divided into two types: internal purification and exhaust after treatment. Zeng (2018) argues that improvements in engine emission reduction technology can reduce NO<sub>x</sub> emissions from ships to a certain extent, but it is difficult to meet IMO Tier III emission requirements. Exhaust gas aftertreatment has a significant effect on reducing NO<sub>x</sub>, SO<sub>x</sub> and PM emissions from ships. Selective catalytic reduction (SCR) is a mature technology that can meet IMO Tier III emission limits. The marine medium and high speed machine SCR



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system installed and developed abroad has been installed on hundreds of ships, and the domestic products have passed the certification of the China Classification Society; In terms of desulfurization, the exhaust gas scrubbing device developed abroad has been promoted in many ships. At present, the research and development of monitoring and control technology for desulfurization systems is a hot issue in this field; In addition, the research on the control requirements of various pollutants for future emission regulations and the research on integrated pollution control devices for ships have made some progress, but they have still been verified by real ship applications.

#### ***2.3.1.4 Ships in port use shore electricity***

The use of shore power by berthing ships can reduce the atmospheric pollutant emissions in the port area during the berthing process. In the United States, Europe and other countries and regions, shore power technology is relatively mature and is in the stage of gradual promotion and application. In China, marine shore power systems have been built in Shanghai Port, Lianyungang Port, Shenzhen Port, Shekou Port, Guangzhou Port and Ningbo Port. The Action of Preventing and Controlling the Pollution from Ships and Ports (2015-2020) has put forward clear requirements for the shore power installation rate of China's port terminals in the future. From 2016 to 2018, the Ministry of Transport organized and implemented the reward work for the use of shore power by ships approaching the port, with a total of 3 batches of 245 projects receiving 740 million RMB. In 2017, the Ministry of Transport issued the Port Power Layout Plan, which further clarified the coastal power facilities construction promotion plan. In 2018, the technical conditions for shore power system of port ships (GBT 36028.1-2018) standard was issued, and the shore power standard system was further improved. In order to solve the problems of power supply and sale qualification, in 2017, the Ministry of Transport, the State Energy Administration and the State Grid Corporation jointly issued the Framework Agreement on Strategic Cooperation to Promote the Use of Coastal Electricity by Ships Arriving at Ports.

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### **2.3.1.5 *Integrated Control Technology for Multi-Pollution of Ships***

Wang, et al (2017) introduced that the multi-polluting integrated treatment technology of ships is a new research direction, and many countries have made some progress. Wartsila and other companies have developed integrated technologies and equipment for the simultaneous treatment of NO<sub>x</sub>, SO<sub>x</sub> and PM emissions. Singapore's Ecospec has also launched the CSNO X three-position integrated ship exhaust treatment system, which is expected to achieve the integrated removal of NO<sub>x</sub>, SO<sub>x</sub> and CO<sub>2</sub> pollution, but it has not yet verified the emission reduction effect.

## **2.3.2 *Current Situation of Monitoring and Supervising Technology of Ship Exhaust Gas Discharge***

### **2.3.2.1 *Technical Requirements for Ship Air Pollution Supervision***

Marine air pollutants mainly refer to sulfides, nitrogen oxides, particulate matter and volatile organic compounds. The exhaust gas generated by the ship's power system, the volatilization of transported cargo, and incineration on board are the main sources of air pollutants in ships. At present, there is no emission standard for marine air pollution, and the exhaust gas emissions of the power system are controlled mainly by controlling the engine performance of the ship and the quality of the marine fuel, for example, ship engine exhaust pollutant emission limits and measurement methods (China's first and second stages) (GB 15097-2016).

Annex VI of the MARPOL Convention, which came into force on May 19, 2005, prevents the air pollution caused by ships from being involved in the control of the above-mentioned various types of atmospheric pollutants and on the incineration of

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ships. Among them, the control of nitrogen oxides is mainly achieved by the emission performance of marine engines, and the sulfides and particulate matter are achieved by delineating fuel quality. On August 23, 2006, MARPOL 73/78 Annex VI entered into force for China, which clearly states that the sulfur content of any fuel used on board ships should not exceed 4.5% m/m; The NO<sub>x</sub> emissions on board are reduced to at least the limits specified in the document; When the ship is located within the SO<sub>x</sub> emission control zone, the sulphur content of the fuel oil used by the ship shall comply with the requirements specified in the document; The fuel used for burning in ships not in the restricted area shall comply with the sulfur content specified in the document.

"Reciprocating Combustion Engine Emissions Measurement" (ISO8178-4:1996) is a standard for shipboard measurement methods commonly used in many countries around the world. Five test cycles are specified for different types of ship engines, but no limit requirements are involved. The "Guidelines for Testing and Testing Nitrogen Oxides Emissions from Marine Diesel Engines" (GD01-2011) issued by China Classification Society is based on the newly revised MARPOL Convention Annex VI of 2008. And the inspection standards revised by the Technical Regulations for the Control of Nitrogen Oxides Emissions from Marine Diesel Engines (resolution MEPC.177(58)), the requirements of direct measurement and monitoring methods are supplemented, and the emission standards of NO<sub>x</sub>, the calculation formula of gas pollutant emission and the test conditions of bench are revised.

The emission limits and measurement methods of marine compression ignition engine exhaust pollutants (the first and second stages of China) being formulated by the Ministry of Environmental Protection will fill in the blank of China's marine air pollution emission standards. The standards stipulate emission limits and measurement methods of exhaust pollutants from ships and aircraft, and are applicable to type approval, production consistency inspection and durability requirements of class 1 and class 2 ships and aircraft used in inland river ships, coastal

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ships, river-sea direct ships and strait (ferry) ships. In November 2018, CCS issued a revised edition of "Guidelines for the Implementation of Emission Limits and Measurement Methods for Marine Engine Exhaust Pollutants", and made some adjustments.

According to the "Notice on Strengthening the Relevant Matters Concerning the Supervision and Administration of Fuel Quality of Ships" (Haijing [2012] No. 527), the domestic trade marine fuel oil implements "Marine Fuel Oil" (the latest version of GB/T 17411); For the foreign trade fuel oil for international routes, the implementation of "Petroleum Products - Fuel (Class F) - Marine Fuel Oil" (ISO8217 latest version). If Annex VI of the MARPOL Convention and its amendments are more stringent than the above criteria, the requirements of international conventions shall be implemented. The International Organization for Standardization voted in 2010 to adopt the latest "Marine Fuel Specifications" (ISO 8217-2010) to accommodate the new requirements of the MARPOL Convention Annex VI Amendment; China released "the revised Standard for Marine Fuel Oil" (GB/T17411-2012) in 2012. "The Ship Fuel Supply Procedures and Test Methods" (GB/T 25346-2010) describe the oil sampling methods associated with ship fuel quality testing.

In August 2015, the Ministry of Transport issued the Action of Preventing and Controlling the Pollution from Ships and Ports (2015-2020). Article 3 of the specific target clearly proposes to promote the establishment of a ship's air pollutant emission control zone to control the discharge of SO<sub>x</sub>, NO<sub>x</sub> and particulate matter from ships; The main tasks are to "strengthen the monitoring and supervision capacity building, establish a transportation environment monitoring network, and improve the transportation environment monitoring and supervision mechanism."

In November 2016, the "13th Five-Year Plan for Ecological Environmental Protection" issued by the State Council proposed "...to implement the management policies for

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the ship emission control areas in the Pearl River Delta, the Yangtze River Delta, and the Bohai Sea, Beijing-Tianjin-Hebei waters, ... Remote sensing monitoring of atmospheric pollutant emissions and oil quality monitoring sites, carrying out ship emission monitoring and joint supervision in the ship emission control area...". The "13th Five-Year Development Plan for Energy Conservation and Environmental Protection of Transportation" clearly defines "promoting the construction of transportation environmental monitoring network, ... improving the ability of ship pollution monitoring and monitoring" as one of the development goals.

In April 2017, the "Implementation Plan for Promoting the Construction of Ecological Civilization of Transportation" was issued by the Ministry of Transport, which is proposed to strengthen the supervision of air pollution emissions from ships, improving the ship emission control area and the construction of ship pollution monitoring and supervision capacity in the Yangtze River Basin, and carrying out ship emission monitoring and joint supervision.

In November 2017, the "Opinions on Comprehensively Advancing the Development of Green Transportation" issued by the Ministry of Transport proposed to "enhance the monitoring and control of ship pollutant emissions monitoring. It focused on the ship emission control area, the ship's air pollutant discharge and water pollutant discharge monitoring and supervision. It also promoted the establishment of joint inter-departmental supervision mechanisms for port and ship pollutant emissions and ship fuel quality. Besides, it helped the air pollution monitoring and law enforcement capacity building of ships, and strictly implementing the relevant requirements for the use of compliant ordinary diesel in ships and rivers and rivers and the use of low-sulfur fuel in ship emission control areas.

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### 2.3.2.2 *Current status of monitoring technology for ship air pollutants*

Developed countries and regions such as the United States and Europe started relatively early, and combined with the requirements of the International Maritime Organization, proposed a multi-faceted monitoring of air pollutant emissions from ships in low-emission control areas. At present, China mainly focuses on marine fuel spot checks and document checks, and the law enforcement and supervision system are far from being flawless. Some scientific research institutes have studied some technical methods which can be used to monitor and supervise the emission of air pollutants from ships. Chang, Zhu and Chen (2017) have given examples such as the Jiaxing Port and Shipping Administration and Shanghai Maritime University jointly developed an inland ship exhaust gas detection system based on new NO<sub>x</sub> and SO<sub>x</sub> fiber sensors. The City University of Hong Kong has developed a mobile ship emission monitoring system based on Internet plus infrared remote sensing technology. Wuhan University of Technology has studied the on-line monitoring system for inland water pollutant discharge based on the AIS/3G terminal expansion method. However, most of these technologies are still in the research stage and have not been put into practical use. China still lacks a systematic on-site monitoring technical system to meet the challenge of air pollutant discharge of ships, and can hardly meet the management needs of prevention and control measures in emission control areas.

According to "The Action of Preventing and Controlling the Pollution from Ships and Ports (2015-2020)", "Implementation Plan on Domestic Emission Control Areas in Waters of the Pearl River Delta, Yangtze River Delta and Bohai Rim (Beijing, Tianjin and Hebei) The documents require that the maritime administrative department should supervise the discharge of air pollutants from ships that are parked or operated in the waters of the emission control zone. The monitoring factors include the sulfur content of marine fuel oil and SO<sub>x</sub>, NO<sub>x</sub> and particulate matter in the exhaust gas; monitoring

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methods include remote sensing monitoring, drone monitoring, regional environmental quality online monitoring, portable on-site monitoring, and online monitoring of ship flue gas exhaust.

The system combs the existing monitoring technologies for waste gas pollutants at home and abroad. From the development process, it is divided into instantaneous sampling, 24-hour continuous sampling-laboratory analysis, automatic monitoring technology; From the technical characteristics, it is divided into traditional chemical methods (electrochemical sensors, thermal conductivity sensors, semiconductor sensors), Modern chemical methods (electrochemical methods, chemiluminescence methods), Conventional optical method (Nondispersive Infrared (NDIR), Nondispersive Ultraviolet (NDUV), laser induced fluorescence technology (LIF)), and spectrometry (Fourier Transform infrared spectroscopy (FTIR), Differential Optical Absorption Spectroscopy (DOAS), Differential Absorption Laser Radar Technology (DIAL)).

According to the characteristics and supervision methods of marine air pollutants, the focus is on the technical products that may be applicable to remote monitoring, online environmental quality online monitoring, portable on-site monitoring, and on-line monitoring of ship's flue gas exhaust. In the monitoring sulfur oxides, nitrogen oxides and particulate matter, there are mature products at domestic and overseas, but the degree of engineering abroad is higher. In terms of individual particle monitoring, domestic products have higher maturity, and rice scattering laser radar technology is widely used.

There are some products in the monitoring equipment market, such as Fourier infrared gas analyzer (Brook, Germany), LD differential absorption laser radar (Raymetrics, Greece), AMBER5 differential absorption radar (EKSPLA, Lithuania), air pollution monitoring laser radar (Zuyev Atmospheric Optics Institute, Russian), tropospheric SO<sub>2</sub> and NO<sub>2</sub> detection laser radar (Angkor Institute of Chinese Academy of Sciences),

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Sentry MS open-circuit ultraviolet differential absorption spectroscopy gas analyzer (Cerex, USA), Air Sentry open-circuit Fourier transform infrared spectroscopy gas analyzer (US, Cerex), EV-Lidar-CAM 3D visible laser radar (Beijing Yifu Herong Technology Co., Ltd.), atmospheric particulate matter monitoring laser radar (Wuxi Zhongke Optoelectronic Technology Co., Ltd.). The above products have not been applied to the monitoring of marine air pollutant emissions, but they are still in the theoretical stage, and the price is expensive. The reliability and applicability of the technology need to be further studied. A growing number of countries are investigating the use of fixed remote sensing technology to inspect high-emission ships, and their inspection results can help law enforcement officers better inspect ships that are most likely to violate regulations, thereby making manpower and other resources more effective use. According to Xing (2016), the Danish emission control zone is piloting the use of remote sensing monitoring technology, and the Danish Maritime Regulatory Authority installed remote sensing equipment on the Öresund Bridge tower platform 25 meters above the water. As long as the smoke emitted by the ship passes through it, the remote sensing equipment can determine whether the ship uses 0.1% sulfur fuel. Of course, there are some errors in this kind of supervision, so the detection standards are appropriately adjusted, and since the smoke emitted by the ship will be affected by climatic factors such as wind direction, not all ships can be monitored, but this method can be initially screened. Violating ships has a certain deterrent power and is worth learning from.

The regional environmental quality online monitoring equipment market is relatively mature, but the monitoring products in line with the national standard are comparatively expensive. The cost of a large number of ship-drilling areas such as waterways and docks is too high to be implemented. Small stations and micro-stationes have been launched in the market, and the price of equipment has dropped drastically. The illegal grid discharge has been identified through regional gridding. The applicability of the technology needs further practical research.



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Portable multi-gas analyzers and portable particulate matter analyzers currently have a large number of mature products on the market, but the applicability of on-site sampling and detection of ship smoke exhaust ports is not clear. Portable fuel oil sulphur analyzers are currently available on the market and are only available from individual manufacturers.

There are a large number of mature products on the market for fixed source flue gas exhaust port, but whether these devices can be installed in the smoke exhaust port of the ship, the reliability of the bumpy environment, and whether the monitoring of the ship main engine and the auxiliary machine exhaust gas can be simultaneously considered. Further practical research is needed.

## **CHAPTER 3:**

### **The main problems of emission control area in China**

#### **3.1 Relevant Implementation Issues of Emission Control Areas**

##### **3.1.1 Difficulties in Promoting Alternative Measures for Emission Reduction**

Cai and Peng (2017) believe that economics and convenience are the main considerations for shipowners to choose pollution control measures. Alternative measures such as shore power, clean energy and tail gas reprocessing currently have varying degrees of deficiencies in terms of economy and convenience, and ships have a lower willingness to use. The energy supply security, operational safety, shore-based and on-board supporting conditions of shore power and LNG power ships are not perfect, resulting in inconvenient use. Liu and Tang (2018) also said that the operating cost of LNG power vessels is higher than that of oil, and the construction cost of shore power and tail gas aftertreatment is higher. Although there are relatively low-cost domestically produced equipment, there are few successful application cases

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and they have not been applied on a large scale.

### **3.1.2 Regulatory capacity to be further enhanced**

Hong, et al (2018) have stated that the water industry has insufficient environmental supervision capabilities. The entire industry has not yet been able to establish a comprehensive environmental monitoring and control mechanism. The overall situation of port environmental monitoring has been weakened and marginalized, resulting in the general lack of normative and effective port environmental monitoring, and the monitoring methods and capabilities of ship pollution are weaker and still in the exploration stage. It is a statutory supervision method to take fuel samples and send them to the laboratory to detect the sulfur content. However, it is time-consuming and laborious, and it is difficult to deal with illegal ships in time. The supervision effect is limited. To this end, China's Ministry of Transport has allocated 109 sets of rapid detection equipment for fuel sulfur content to grass-roots maritime institutions. At present, all equipment has been put in place. The sampling survey of one-month use shows that the rapid detection equipment has good stability and can help maritime law enforcement personnel to determine whether the ship uses compliant low-sulfur oil on site. However, from January 1, 2019, low-sulfur oil should be used when the ship enters the waters of the emission control zone. The scope of supervision of the maritime agency should be expanded to the entire waters of the emission control zone. Existing regulatory technologies and equipment will be difficult to adapt to regulatory needs (Yu, et al, 2018).

### **3.1.3 Insufficient capability of advanced technology and independent innovation**

Through preliminary comparative research, there is a big gap between China's cutting-edge technologies such as shore power, exhaust gas aftertreatment, and

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compressed natural gas power vessels and international advanced levels. Many domestic pilot projects also use imported technology equipment (Chang, et al, 2017). The low level of localization of advanced technology and insufficient ability of independent innovation are the main reasons that restrict the popularization and application of marine pollution prevention and control technologies, such as shore power, tail gas post-treatment, and further reduce pollutant emissions. Therefore, it is urgent to systematically sort out the frontier technology of ship pollution prevention and control, and carry out technical research work.

#### **3.1.4 Standard Policy for Perfection and Perfection**

The lack or imperfection of standards, norms and related policies is a prominent problem facing the current ship pollution prevention and control work. Relevant standards and norms fail to cover all aspects of pollution discharge. Moreover, the management requirement is low and the compulsory force is weak. The problem of "international is higher than domestic, and coastal is higher than inland river" is widespread. To a certain extent, it restricts the development of ship pollution prevention and control. There is a lack of technical standards for ship exhaust gas post-treatment technology, multi-pollutant co-treatment technology, LNG technology and so on. The standards of shore electricity and oil spill emergency need to be revised and improved urgently. It is also necessary to formulate corresponding promotion and incentive policies for existing mature marine pollution prevention and control technologies. Therefore, it is urgent to put forward suggestions for the revision of standards and policy measures based on the construction of the technical system of ship pollution prevention and control (Li, et al, 2017).

#### **3.1.5 Multi-sectoral collaboration mechanisms still not sound**

The prevention and control of port pollution involves many departments such as port

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and shipping, maritime affairs, environmental protection, municipal administration, and fishery administration. At present, effective linkage and communication mechanisms have not been formed between various departments, and it is difficult to form a joint force for pollution prevention and control, which restricts the implementation of industrial environmental management policies.

### **3.1.6 Industry Environmental Protection Infrastructure Capacity to be Strengthened**

Yin (2017) has said that the construction of pollution treatment facilities at port terminals is still not satisfying. Some old terminals are not equipped with adequate sewage treatment facilities or dust control equipment. The utilization efficiency of self-built treatment facilities in some port areas needs to be improved; At the same time, the distribution of receiving and processing facilities for ship pollutants is not reasonable enough, lack of social clean-up force supplement, less related equipment and lack of systemicity, and cannot meet the needs of ship pollution prevention and control.

## **3.2 Relevant Technical Problems of Emission Control Areas**

### **3.2.1 Problems Existing in Ship Air Pollution Control Technology**

Although various air pollution control technologies have made certain progress, there are still some problems in scientific research and application, as follows:

#### ***3.2.1.1 Insufficient Basic Conditions for Replacing High Quality Marine Fuel***

The investigation found that the production and supply capacity of marine fuel oil

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with sulfur content of 0.5% or less is insufficient, which is one of the bottlenecks in the future measures to switch to low-sulfur oil. Specifically, the marine fuel oil supplied on the market can be classified into domestic trade oil and foreign trade oil according to the source. The domestic trade oil is mostly from Sinopec and CNOOC refineries. After blending with shale oil and coal-to-liquid, the sulfur content can be reduced to less than 3.5% m/m. The sulphur content of marine fuel oil in the market is between 1.3-4.5% m/m, and the current price is around 1040-5100 yuan/ton (mostly 2000-3000 yuan/ton). The quantity of the ship fuel with less than 0.5% m/m of sulfur is small. If the future upgrade is to replace the fuel with sulfur content less than 0.1%, the domestic fuel supply capacity will be lower. In terms of foreign trade oil, there are two suppliers of low-sulfur oil of 0.5% m/m in Singapore. Among them, Shell's oil quality is stable, but the viscosity is low, which is easy to damage the engine, while the SK company's oil products have unstable quality problems. In addition, marine diesel fuel supplied by formal enterprises in the market can basically meet the national III standard, but many marine diesel fuels supplied by informal enterprises are of poor quality, and the sulfur content generally exceeds the national III standard.

### ***3.2.1.2 LNG Dynamics and Safety***

Compared with diesel fuel, the calorific value of the mixture is lower, the intake (air) volume is less, the molecular change coefficient is smaller, and the power performance will decrease. If the matching is poor, the power performance will deteriorate to an astonishing degree. As a dangerous chemical, LNG is also an important risk source because of its physical and chemical properties. The main component of LNG is methane, which is a compressible and flammable gas. Its hazards include low temperature frostbite, combustion, explosion, asphyxiation and so on. When LNG is used as marine engine fuel, the main safety problems of LNG/dual-fuel diesel engine are low temperature, leakage and explosion due to the enclosed engine compartment space.

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### ***3.2.1.3 The improvement of technology of matching nitrogen removal and desulfurization equipment with high-power diesel engine***

At present, there are some problems in the matching of denitrification system and desulfurization system with high-power diesel engine, which are the key technical problems to be solved urgently. In addition, the development of SCR technology in denitrification technology is also constrained by factors such as temperature control of exhaust gas, catalyst deactivation, urea quantitative injection, uniformity of mixing with waste gas, etc. The technology level needs to be further improved.

### ***3.2.1.4 Shore-ship power supply system***

The power supply frequency of China's port power grid is 50Hz, which are voltage levels of 10kv, 6kv and 360v respectively; The power frequency of the berthing ship is 50 Hz and 60 Hz. In addition to the voltage level of China, the voltage is 11kV, 6.6kV, 690V and 440V. The shore power system needs to be equipped with variable voltage or frequency conversion equipment to convert the terminal supply power into a voltage and frequency consistent with the ship's power. The current level of shore power equipment technology is difficult to achieve the needs of a single port shore equipment compatible with a variety of different types of ships.

### ***3.2.1.5 Coastal Power System on-load transfer technology***

Due to the lack of corresponding standards for shore-to-shore communication in shore power system, it is difficult for shore power supply equipment to accurately read the parameters of grid-connected ships, which has a great influence on the automatic confirmation of parameters and the correction of its own parameters. As a result, the

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ship power supply system and auxiliary power generation system may bring harmful impact to the ship power supply system in the process of on-load transfer, threaten the safety and stability of the ship power system, and affect the normal operation of the ship.

#### ***3.2.1.6 Improvement of Ship multi-pollutant cooperative treatment technology***

At present, some treatment technologies and devices have been developed for sulfur oxides, nitrogen oxides and particulates in ships. However, facing the control requirements of future emission regulations for multiple pollutants, the integrated and cooperative treatment technology of multiple pollutants will become one of the important technologies in the future. However, most of the technology is still in the stage of principle research and laboratory research and development, and there is no real ship application, and the technology level needs to be further improved.

#### ***3.2.1.7 Large water level difference wharf and anchorage shore power technology***

Due to the large water level difference of some inland river terminals, the use of shore power is difficult; In addition, multiple ships in the anchorage are docked in parallel, and shore power usage will also interfere with each other. The above two problems are the main problems faced by the inland rivers, especially in the Three Gorges waters. Therefore, it is necessary to study key technologies such as the construction and application of large water level wharfs and anchorage shore power, to solve the problem that it is difficult to reasonably arrange charging piles and cables due to large water level drop, and to promote parallel use of shore power by multiple ships in the anchorage area.

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### **3.2.2 Shore-ship power supply system is difficult to match**

#### ***3.2.2.1 Ship multi-pollutant cooperative treatment technology***

Due to the particularity of marine air pollutant monitoring, existing environmental monitoring technologies and standard specifications are not fully applicable.

There are problems such as insufficient monitoring support for marine air pollutants by existing environmental monitoring technologies, and insufficient standardization and standardization of monitoring technologies.

For the determination of ship exhaust gas, because the "Contamination Standard for Ship Pollutants" (GB 3552-83) does not have requirements for exhaust gas monitoring, in the actual test process, it is mainly sampled and measured with reference to relevant standards such as boilers. The ship has fluidity and certain commerciality, requires short monitoring time, and the monitoring method must conform to the national standard and is easy to operate. How to accurately select sampling methods and testing methods has become a major constraint in practical work.

#### ***3.2.2.2 Lack of mature technical means for monitoring air pollution emissions from ships***

At present, the monitoring of ship sewage and garbage emissions mainly depends on the maritime department on board the ship to check the ship's record of the direction of the pollutants, as well as the ship's regular statistical reports, lack of direct monitoring. The regulation of air pollution emissions is mainly based on the supervision and inspection of engine and fuel quality. Strict control of engine performance can be achieved through inspections such as pre-certification inspection, initial certification inspection, periodic inspection and periodic inspection of the engine; The implementation of fuel quality inspection is relatively weak, and there are



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problems such as insufficient funds, insufficient staff, and difficulty in accountability.

## **CHAPTER 4:**

### **Suggestions and safeguards for the future development of emission control areas in China**

#### **4.1 Necessity of China's Emission Control Areas Adjustment**

##### **4.1.1 Domestic Demand**

The continuous implementation of air pollution prevention and control actions to achieve continuous improvement of air quality is not only to meet the expectations of the people's better life, but also an important action for China to play the role of a responsible big country and actively participate in important actions for better development of the global governance system. At present, all industries have taken active actions, and air pollution control has been strengthened. China's Ministry of Transport has also proposed "continuing the implementation of the ship emission control zone policy, timely research and establishment of emission control areas with stricter emission requirements, more control of pollutant types and a larger spatial scope."

Since the establishment of the emission control zones, the concentration of sulfur oxides around the urban ports in the control area has been significantly reduced compared with the previous ones, contributing to the first phase of China's air pollution prevention and control actions.

##### **4.1.2 International Situation**

In recent years, the International Maritime Organization has vigorously promoted the prevention and control of marine air pollution, and low-sulfur oil will be widely used

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in global waters by 2020. Countries around the world gradually strengthen their control over nitrogen oxide emissions, the results of the predictive assessment show that controlling the NO<sub>x</sub> emissions of ships has a significant contribution to regional environmental protection, and has little negative impact on the shipping industry and regional economy. The major shipping countries have started in-depth discussions on the ship energy efficiency design index. It is foreseeable that IMO will definitely propose specific requirements for improving energy efficiency and controlling greenhouse gases in the future. China can combine emission control zone adjustment research and prepare for improving energy efficiency and greenhouse gas control.

## **4.2 China's Emission Control Areas adjustment ideas and plans**

### **4.2.1 Adjustment Thoughts**

It is of necessity to be fully aware of the concept of green development, to establish a ship emission control zone with stricter emission requirements, to control a more comprehensive range of pollutants, and a wider range to promote the ecological civilization construction of the transportation industry.

On the basis of the implementation experience of the current emission control areas, according to the domestic and international situation and the emission reduction demand of China's air pollution status, It is necessary to increase control requirements for nitrogen oxides and volatile organic compounds, and scientifically establish control requirements; meanwhile, consider synergies with other green development policies, combine pollution emission reduction and regulatory technology development trends and operational safety and other factors to rationally apply alternatives to emission reduction.

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## 4.2.2 Control Measures

### 4.2.2.1 *Control of sulfur oxides and particulates*

Reducing the sulfur content of fuel is the main means of controlling the emission of sulfur oxides and particulate matter from mobile sources at home and abroad. With reference to the practice of other international emission control areas, the fuel sulfur content limit should be considered to be “not more than 0.1% m/m”. At present, the low-sulfur fuel below 0.1% m/m that the ship can apply has higher price. According to the survey in 2017, 0.5% m/m of low-sulfur domestic trade oil is available, and low-sulfur oil below 0.1% m/m cannot be produced through blending, and has not yet formed a stable domestic oil supply capacity. Therefore, if the ship is required to use 0.1% m/m or less of low-sulfur oil in a wide range, the domestic trade ship may face difficulties in refueling or excessive cost in a short period of time. The adjustment scheme can be selected to include “fuel with sulfur content  $\leq 0.1\%$  m/m into the emission control zone” or “fuel oil with sulphur content  $\leq 0.1\%$  m/m during ship docking”. After further consultation, various factors need to be considered comprehensively, and scientific and feasible control requirements should be selected. In the long run, an economically stable supply of low-sulfur oil may be generated due to market demand.

### 4.2.2.2 *Control of Nitrogen Oxides*

The main measures to control the emission of nitrogen oxides from ships are modification of engine interior, dilution of exhaust gas circulation or installation of exhaust gas disposal system behind engine. Zhou (2018) said that both domestic and foreign engines can meet Tier II requirements, but cannot directly improve the engine to the Tier III standard. Most of the ships entering the emission control zone chose post-fuel denitrification technology, and about 10% of the vessels chose to retrofit the

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exhaust system for exhaust gas circulation.

According to international control experience, Cheng (2019) stated that it is relatively feasible to propose control requirements for new shipbuilding, and it is difficult to perform control requirements on ships. The engine is the core component of the ship. The price of the ship's main engine can generally account for about 10% of the total cost of the ship. The capital and time cost of replacing the engine or modifying the engine exhaust system is high. The technology and equipment for post-nitrogen denitrification treatment are relatively mature. Although China's R&D is slightly later than Europe and the United States, some domestically produced equipment has passed CCS certification and started to turn to real ship applications.

However, the denitrification equipment is relatively large, and there is often not enough suitable installation space in the ship, and the one-time investment of the equipment is still high, and the price is about 20%-35% of the host. At the same time, China is a party to the 1982 United Nations Convention on the Law of the Sea. The requirements for pollution control of foreign ships within the territorial sea should give priority to respecting its "innocent passage". Under the current technical conditions, it is not suitable for foreign vessels to exceed the requirements of the MARPOL Convention for nitrogen oxides control. Considering the connection with domestic and international standards, it is recommended that the Chinese marine vessels built after a certain preparation period strictly enforce the Tier III limit requirements, and the inland river boats and rivers and seas direct ships are implemented in accordance with the ship's standards. Relevant departments have begun to study the feasibility of subsidizing the treatment of equipment after the installation of tail gas by ship. After the conditions are mature, the control requirements for nitrogen oxides during the navigation of the ship can be proposed. In contrast, denitrification equipment has a lower operating cost, which is only 1-2% of the cost of a ship's fuel. Ships that use denitrification equipment generally do not use shore power for economic reasons.

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#### 4.2.2.3 *Alternative measures for emission reduction*

At present, the use of clean energy such as LNG, the installation of exhaust gas after treatment, the use of shore power and other technologies are relatively mature, and have been applied in different degrees at home and abroad.

LNG clean energy still has a lot of controversy about the emission reduction effect of nitrogen oxides. In some tests, nitrogen oxide emissions have been higher than traditional fuels. Presently, there are no domestic engines that can reach Tier III standards. At the same time, inland river LNG power vessels often have problems of excessive gas escape rate, which is not conducive to the coordinated reduction of atmospheric pollutants and greenhouse gases. The application of LNG energy also has many problems such as incomplete matching of filling stations and unsatisfactory safety supervision mechanism.

Exhaust gas after-treatment technology is more mature than denitrification, but its desulfurization efficiency is much lower than that of desulfurization process in fuel refining process, and it will bring secondary pollutants such as washing liquid, compared with the replacement of low-sulfur oil. There are no obvious advantages in terms of ease of operation and cost. At present, the desulfurization and denitrification technologies have not solved the problem of coordinated operation, and ships usually only choose to use one of them.

In recent years, shore power technology has been advancing rapidly. However, there are still problems in terms of safety, connection time and labor, and ship-shore mismatch. At present, the relevant mechanism policies for shore power use are being studied and formulated.

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At present, the conditions for the widespread promotion of LNG clean energy vessels are not yet mature, and ships can preferentially choose post-nitrogen post-treatment technology and shore power technology when conditions permit.

### **4.3 Relevant Technical Requirements for Ship Air Pollution Prevention and Control**

#### **4.3.1 Ship Air Pollution Control Technology**

##### ***4.3.1.1 Technical Requirement Analysis***

As a major shipping country in the world, China's Beijing-Tianjin-Hebei, Pearl River Delta and Yangtze River Delta regions have high density of ships, and their air pollution control problems have gradually received attention from all walks of life. Domestic and foreign media published relevant articles, arguing that shipping is a very important source of air pollution in China. In recent years, the state has repeatedly received a motion on “calling for pollution control of ships”. The control of air pollution in ships in China is imminent.

In addition, with the implementation of the strategy of the Yangtze River Economic Belt and the Maritime Silk Road, China's transport capacity structure will be greatly adjusted to the direction of water transport, and the shipping industry will usher in a new round of rapid development. “Standardization” and “cleaning” will be the water operation industry. The future development direction is an important measure to implement "green transportation." It is necessary to actively carry out the prevention and control of air pollution in ships.

##### ***4.3.1.2 Technology Development Trend Analysis***

Replacing high-quality marine fuel is one of the effective means to achieve emission reduction of marine air pollutants, especially sulfur oxides. It has the advantages of

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simple operation, low cost, and obvious emission reduction effect. This is an effective means to control the pollution of ship exhaust rapidly at present, and it will also be an important means to control the pollution of ship exhaust in the future. However, due to the use of high-quality marine fuel, the effect of reducing nitrogen oxides is not obvious. Therefore, in the long-term development of multi-pollutant integrated emission reduction technology, or the increasingly strict requirements of pollution control, the means of reducing emissions of low-sulfur oil may be phased out.

Li, et al (2019) study shows that natural gas dual-fuel powerboats can supply natural gas as compressed natural gas (CNG) and liquefied natural gas (LNG). Recently, domestic CNG technology has matured and has been widely recognized and promoted. The research on diesel-LNG hybrid ships in China has also achieved initial results. Due to the lack of relevant laws and regulations and supporting facilities, the promotion of LNG power use is still in its infancy, and its practical application is mainly concentrated in several countries in Northern Europe. China's LNG power ship is in the research and experimental stage. The construction of China's domestic LNG power ship and filling station has made great progress, but the development of coastal LNG power ship is relatively slow. At present, the industrial environment for promoting the use of inland river LNG power vessels in China has gradually matured. In the next step, China should speed up the planning and constructing LNG refueling points and lay the foundation for the comprehensive promotion of inland LNG power vessels.

At present, the batteries of electric ships are mainly lithium batteries (lithium iron phosphate batteries). Recently, lithium iron phosphate batteries, fuel cells and super capacitors have been the main development directions. From the technical and practical point of view, electric ships are mainly subject to battery life and charging speed. Inland navigation (medium within 2000 gross tonnage and route distance within 100km) in medium and short-distance transportation and medium and small-sized transportation can meet the demand. However, for coastal and ocean

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shipping that transports goods in large quantities over long distances, technical breakthroughs are needed.

The technology improvement of marine engine and exhaust aftertreatment technology are important pollution control technologies besides the use of shore power and cleaner marine fuel. At present, there are few ships using denitrification or desulfurization technologies such as SCR, but with the improvement of international and domestic requirements, denitrification systems and desulfurization systems with high pollutant emission reduction efficiency will increasingly become the mainstream of ship pollution control technology.

Lin (2019) has done some research on offshore power, Lin (2019) points out that the use of offshore power by ships in port is one of the important technical methods to reduce air pollution during the period of port landing. The future of shore power technology will focus on modularization of shore power equipment; perfecting the technical standard system; ship-shore integrated monitoring and protection; automation of shore ship connection operation; large capacity shore-based power supply technology; accelerating the development and application of key technologies such as large water level difference wharf and anchorage shore power, and the perfection of standard and norm system.

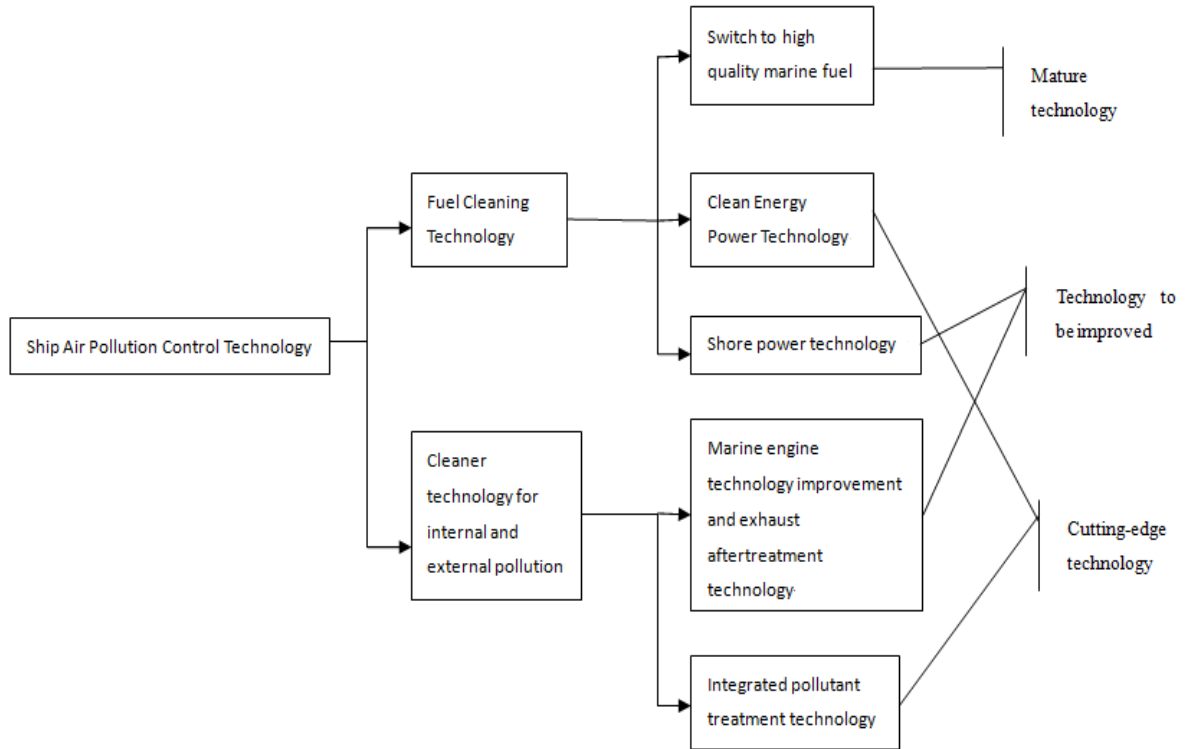
Ship multi-pollutant synergistic treatment technology needs further research and development. Fang, et al (2017) have said that in the face of future pollutant emission laws and regulations on the control requirements of multiple pollutants, ship multi-pollutant co-processing technology is one of the ways to solve this problem efficiently. At present, many research institutions in China and abroad have carried out research on integrated pollution control technologies and devices for ships. After the technology and equipment are mature, it will be an important technology for implementing ship pollution control in the medium and long term.



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### 4.3.1.3 Technical Framework System and Classification

The classification and main problems of ship air pollution control related technologies are shown in Figure 4.3.1.3-1.



**Figure 4.3.1.3-1: Technical framework of ship air pollution control**

### 4.3.1.4 Frontier Technology Development Direction

The denitration system matches the key technologies of high-power diesel engines. Including: denitration system parameter optimization technology research; high-power diesel engine matching technology research, establish and optimize matching calibration system; denitration system long-term operation adaptive matching technology research (Wang, 2017).

The key technology of matching desulfurization system with high-power diesel engine includes parameter optimization technology of desulfurization system adaptive

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control technology of matching diesel engine, integrated optimization technology of ship desulfurization system and diesel engine.

Matching optimization technology of shore power system includes shore-ship integrated modeling technology, multi-system and multi-quality compatibility technology and large capacity shore-power system technology.

Ship shore connection technology includes ship-shore automatic grid-connected technology, ship-shore connection system standardization, ship-shore information interaction technology, large water level terminal and anchorage shore power technology.

Shore power system protection technology. These include fault condition simulation technology and operational safety protection technology.

Key technologies for integrated treatment of ship high-power diesel engine emissions. Specifically, there are research and development of marine supergravity vortex absorption technology, compact high-efficiency and strong oxidation technology, integrated treatment device integration technology, and integrated treatment device matching technology.

LNG power system anti-leakage technology and full ship LNG detection and monitoring safety alarm control technology. Although LNG is an economical and green energy source, its own characteristics determine the security risks in its use. Conduct research on leakage of LNG powerboats to help achieve safe use of LNG powerboats. The monitoring of flammable gas concentration is an effective measure to prevent accidents in LNG powered ships, also easy to find and repair

In addition, it is also possible to develop LNG ships to supply ship power technology, and to use the propulsion system for new LNG ships, and the electric propulsion

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technology is more energy-saving and environmentally friendly.

Finally, It is supposed to develop the electric ship technology of lithium iron phosphate battery, fuel cell and super capacitor to improve battery life and charging speed.

### **4.3.2 Ship Exhaust Pollution Monitoring Technology**

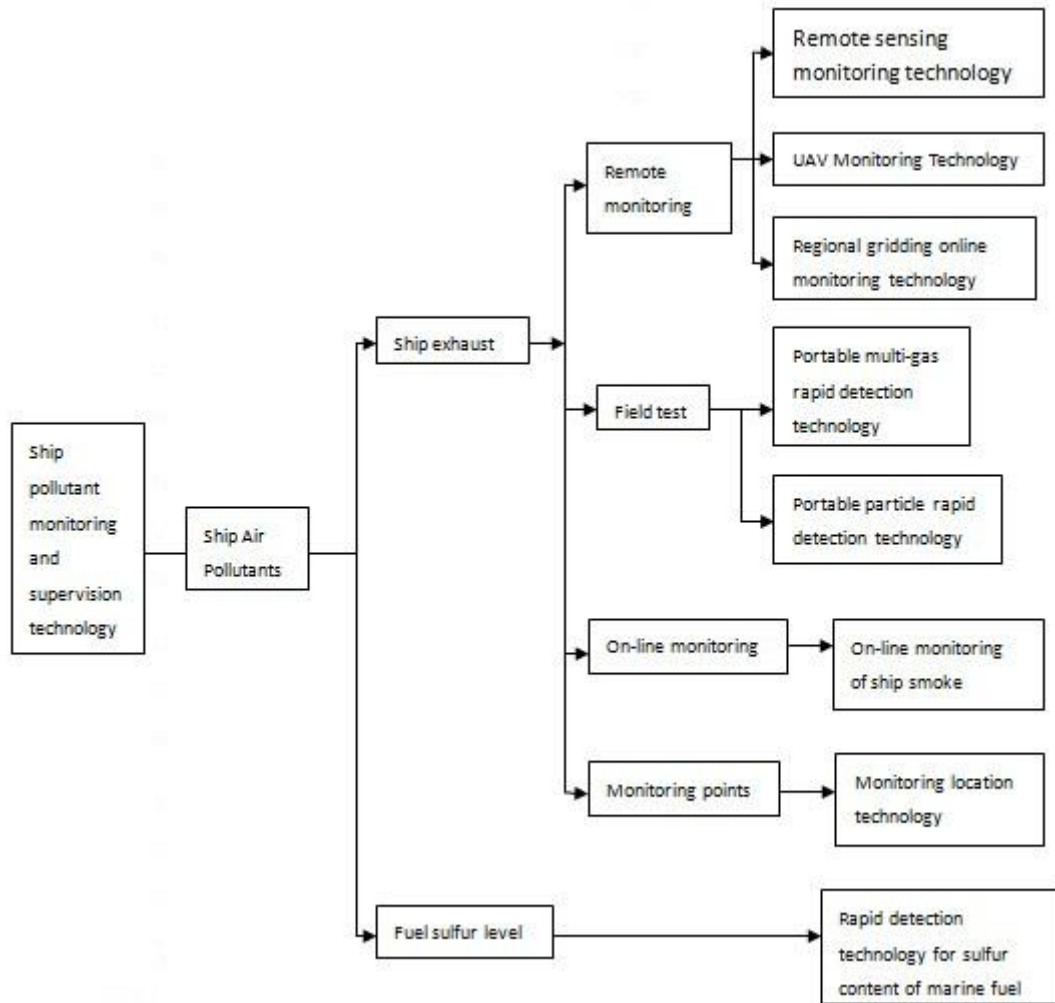
#### ***4.3.2.1 Technical Requirements Analysis***

In order to meet the needs of conducting ship air pollutant monitoring and supervision technology research, it is necessary to support the effective supervision of ship emission control areas. Corresponding monitoring technology equipment is required:

Remote monitoring of technical equipment; regional gridding online monitoring technology equipment; portable monitoring technology equipment; ship smoke online monitoring technology equipment. China still has a large gap with developed countries in terms of remote sensing monitoring technology and flight monitoring technology for marine air pollutants.

#### ***4.3.2.2 Technical Framework System and Classification***

Ship pollutant monitoring and monitoring technologies mainly include ship air pollutant monitoring technology and ship water pollutant monitoring technology. The specific technical framework is shown in Figure 4.3.2.2-1.



**Figure 4.3.2.2-1: Technical Framework System and Classification of Ship Pollutant Monitoring and Supervision**

### 4.3.2.3 *Frontier Technology Development Direction*

For the cutting-edge technology with strong development potential, the next major research direction or technical development route is proposed.

Ship exhaust gas remote sensing monitoring technology, which taking into account the particularity of ship air pollutant monitoring, the ship exhaust gas remote sensing monitoring pilot is carried out in some ports, and the ship exhaust gas remote sensing monitoring equipment with relatively reliable R&D results, relatively high precision, large coverage area, relatively simple operation and fast response is provided.

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Ship tail gas monitoring and distribution technology. As a mobile source, the ship has a wide range of space activities. Studying the ship exhaust gas monitoring and distribution technology plays an important role in improving the representativeness and reliability of the ship's spatiotemporal activity level.

#### **4.4 Supporting Measure**

##### **4.4.1 Enhancing Fuel Supply Guarantee**

In accordance with the relevant guidance requirements, It is supposed to continue to promote the low-sulfur oil supply system, fuel standard revision, multi-sector joint law enforcement, information sharing in all aspects, and other aspects, and strengthen the supply of compliant marine fuel.

##### **4.4.2 Accelerating the Revision of Ship Inspection Code**

The proposed requirements for controlling nitrogen oxides and volatile organic compounds, as well as alternative measures such as shore power, LNG clean energy and tail gas post-treatment, are related to ship design, construction and operation. The revision of relevant technical specifications for ship inspection should be speeded up to ensure ship safety.

##### **4.4.3 Promotion and Encouraging Policies of Applicable Technologies for the Prevention and Control of Ship Air Pollution**

###### ***4.4.3.1 Ship Air Pollution Control Technology***

At present, the marketization of ship air pollution control technology in China is not high, and the application environment of shore power, LNG power ship and ship exhaust treatment is not yet fully mature. Only ship replacing with cleaner marine fuel

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measures is widely used.

The measures of replacing low sulfur oil should be popularized. Improve the shore power system to promote the relevant supporting system will be improved, the supervision of ship air pollution control will be strengthened, the relevant standards, norms and supporting policies for electric will be established and improved.

#### ***4.4.3.2 Ship Exhaust Pollution Monitoring Technology***

Aiming at the application and popularization of advanced and mature technologies, such as portable rapid detection technology of ship flue gas, rapid detection technology of sulfur content in marine fuel oil, etc. Next, the maritime department should establish the working mechanism of ship pollution monitoring as soon as possible and formulate the work programmer of ship pollution monitoring. Define annual monitoring work plan, monitoring mode, monitoring factors and frequency, and issue technical framework system and guidance for classification and technology selection of ship pollution monitoring. Effectively promote the implementation of ship pollution monitoring.

## **CHAPTER 5:**

### **SUMMARY and CONCLUSIONS**

Firstly, this paper describes the efforts made by countries, regions and international organizations in the world to maintain the marine atmospheric environment, and then discusses the development status of China's ship air pollution prevention and control measures. According to the existing policies and requirements of emission control areas in China, this thesis introduces the work of emission control areas (ECAs) in China and evaluates their environmental benefits. It shows that the emission control

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areas in China are developing in an orderly manner, and that the air pollution of ships in this area is effectively prevented and controlled. However, there are still some problems to be solved in the application of emission control areas in China. For example, emission control areas do not involve some major ports, technology and independent innovation capabilities need to be strengthened, and follow-up policies and legislation need to be improved.

Based on the analysis and research of ship air pollution prevention and control technology, ship and port air pollution monitoring and supervision technology, the next research direction of ship port pollution prevention and control technology in China and the catalogue of applicable technology are summarized and refined. In the past five years, we need to focus on the research and development of key technologies and equipment, such as post-treatment and pre-treatment technology of ship exhaust emissions, construction of ship port environmental monitoring platform, etc. Promote the technology of shore power system and comprehensive dust removal for large dry bulk terminals, and promote the development of a number of key technologies and major equipment with independent intellectual property rights. It is helpful to fulfill the requirements of APPCAP for pollution prevention and control of ports and ships.

Generally speaking, the future development of China's emission control areas needs to rely on the development of related technologies. At the same time, we should actively build the system standards of China's emission control areas, and we cannot ignore the cooperation with international technology and regulations. In order to ensure the further improvement of China's emission control areas, the competent transport departments at all levels should strengthen organizational leadership and coordination, refine tasks and measures, and clarify the division of responsibilities. Actively coordinate relevant state departments and local governments to promulgate relevant policies and formulate technical standards; Promote information sharing, carry out joint law enforcement, establish a linkage mechanism for supervision and management, and jointly promote the development of emission control areas.

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The world has begun to attach importance to the construction of emission control areas, and IMO's requirements are also constantly stressing the importance of environmental protection. The related technologies of air pollution control and supervision and the need to be green, safe and effective all have an important impact on the development of related technology industries in China. China is a big maritime country. There is still room for improvement in the supervision, management and control of ship pollution prevention. In order to effectively control marine pollution, the current development trend is becoming more and more unified in global standards and objectives. It is necessary to build a strong, intelligent and green prevention and control mechanism.



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