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Ship pollution risk assessment of Taicang Port

Shuai Shuai

WORLD MARITIME UNIVERSITY

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SHIP POLLUTION RISK ASSESSMENT OF TAICANG PORT

By

SHUAI SHUAI

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DECLARATION

I certify that all the materials in this research paper that are not my own work has been identified, and that on materials are included for a degree has previously been conferred on me.

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

(Signature) Shuai Shuai

(Date):August 5, 2016

Supervised by: Xiong Deqi

Professor of Dalian Maritime University

Assessor:

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ABSTRACT

Title of Dissertation: **Ship Pollution Risk Assessment of Taicang Port**

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Taicang port is located in the Yangtze River Delta region, one of the most developed areas in China. As an inevitable passage of the ship in and out of the Yangtze River, the number of ships and cargo volume in and out of Taicang port has increased continuously in recent years. At the same time, Taicang port is facing an unusually complex and severe pollution situation, and in the event of a major ship pollution accident, the local and the surrounding ecological environment and residents' lives will be seriously affected. Research on the risk and emergency management of ship anti-pollution in Taicang Port and giving the corresponding countermeasures so as to effectively prevent the occurrence of ship pollution incidents has important practical significance.

This paper firstly researches the Taicang Port ship pollution control situation, and detailed introduces the conditions and planning of Taicang port, the general situation of ship and cargo, and the main risk sources. Then the author detailed analyses and summarizes the risk factors which influence the water pollution from vessels, lists the risk factor evaluation system table, uses AHP method to calculate the factor percentage, and analyses the existing problems and reasons of Taicang Port according to the risk percentage. Finally, combined with the professional knowledge and find the current mechanism and the related problems, the author puts forward the countermeasures to control of pollution from ships.

KEY WORDS: ship, ship pollution prevention, risk assessment, emergency response

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CHAPTER 1

Introduction

1.1 Research background

In recent years, with the rapid development of shipping, the Yangtze River has become the world's largest and busiest navigable river. With the development of oil, chemical industry, energy, gas and transportation and other industries along the Yangtze River, the freight volume of dangerous goods transported by the Yangtze River has increased significantly, and the number of dangerous goods transport vessels and dangerous goods loading and unloading terminals has increased rapidly.

As the first port of the Yangtze River, Taicang port has a sustained and rapid development of the port economy. According to the Statistical data from the official website of the Jiangsu Maritime Safety Administration, Taicang port cargo throughput reached 203 million tons, and container throughput reached 370.61 million TEUs in 2015. However, with the rapid growth of the shipping industry, the problem of environmental pollution especially water pollution faces big risk. The ships entering or leaving Taicang Port include sea going ships and inland river vessels with different condition and uneven quality of the crew, which not only affects the economic development of Taicang port, and also becomes a major livelihood issue for the local residents.

1.2 Research significance

With continuous improvement of Taicang's economic development and residents' living standards，the ecological environment, especially water environment in Taicang Port, is facing unprecedented pressure. All kinds of sudden water pollution accidents occur frequently in China, and it becomes a serious threat to the water quality of the environment, especially the centralistic drinking water sources, which are closely related to people's life and health.

Based on the analysis of the influence factors of the pollution of the ship in Taicang Port, It is scientifically supported to establish the risk factors table of the ship, to research on the current situation of ship pollution control in Taicang port and find the problems and deficiencie. Based on the advanced experience from domestic and foreign countries, it is reasonable to put forward reasonable suggestions and protect the water environment in Taicang Port.

1.3 Research contents

The first part is to research ship pollution control situation of Taicang Port, learn from excellent domestic and international ship pollution control methods and experience, detailed introduct the conditions and planning of Taicang port, the general situation of ship and cargo and the main risk sources.

The next part is to analyse and summarize the risk factors which influence the water pollution from vessels in detial, list the risk factor evaluation system table, use AHP method to calculate the factor percentage, and analyse the existing problems and reasons of Taicang port according to the risk percentage.

The last part is to draw lessons from the method and theory of domestic and foreign

control of pollution from ships, combin with the professional knowledge and find the current mechanism and the related problems, put forward the countermeasures to control of pollution from ships, improve the area of the ship pollution control level and effectively control the marine pollution risk.

1.4 Research method

1.4.1 The method of documentary analysis

A variety of relevant literature including the international conventions and domestic laws and regulations, CNKI database, Internet, newspapers, magazines and expert works are collected and analyzed. The main contents collected and analyzed are about ship pollution control technology and management, which can provide a reliable theoretical basis for this paper .

1.4.2 The method of expert investigation

According to the actual situation of Taicang Port, one of the methods is to collect the relevant expert advices through the form of questionnaire. After the statistics and analysis of expert advice and opinions, the author objectively and comprehensively evaluated the experience and judgment of experts and determine the proportion of the indicators influencing the risk assessment of ship pollution in Taicang port, so as to prepare for the calculation of the weight value of each evaluation factor by analytic hierarchy process.

1.4.3 The method of analytic hierarchy process

In this paper, through the collection of relevant historical data of Taicang port, the factors influencing the risk assessment of ship pollution in Taicang port are summarized. To establish the evaluation system by AHP method and computer software to calculate the factor percentage, to the purpose is to provide data support for the analysis of the existing problems in Taicang Port.

CHAPTER 2

Analysis of Present Situation of Taicang Port

2.1 General situation of Taicang Port

Taicang port is located in the Yangtze River and the coastal open interchange, with 38.8 km shoreline of Yangtze River, and - 12.5 meters deep-water channel, and is a rare natural harbor in China. Since the beginning of the new century, in order to guarantee the development of the open economy of the Yangtze River Delta and Jiangsu Province, The Chinese government attached great importance to the Taicang port. As an important part of Shanghai international shipping center, container trunk line port and transit hub port for river-sea coordinated transport, Taicang port has become the first foreign trade port in Jiangsu province. In 2011, Taicang Port throughput exceeded 1 million tons,3 million TEUs, which is one of the rare port throughput exceeded million tons of inland ports.

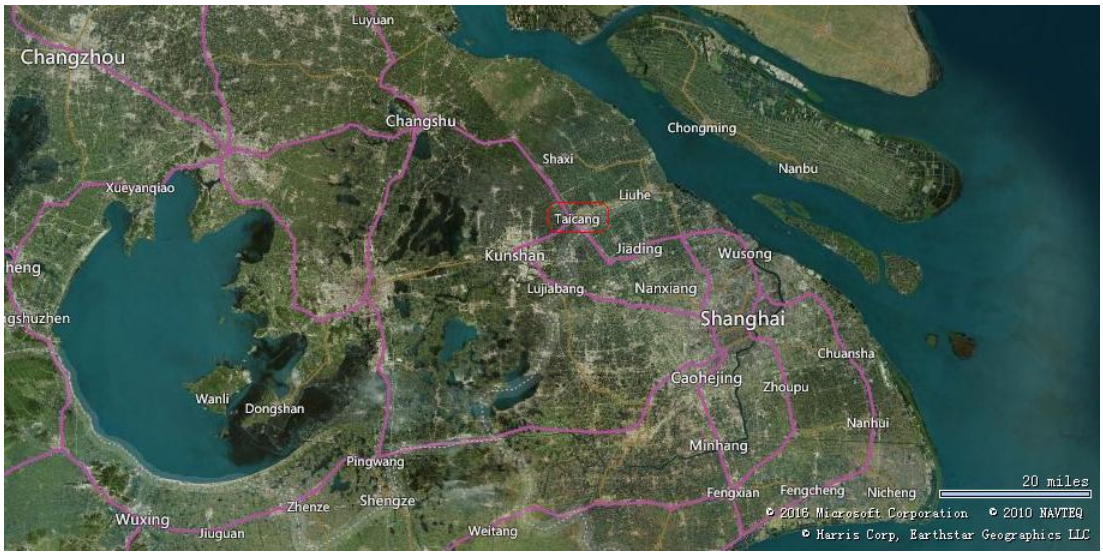

Figure 2.1:The situation of Taicang Port

2.2 Port and channelcondition

Located in the South Bank of the Yangtze River Estuary and only 60 km from Shanghai city center, the geographical position of Taicang port and the establishment of the port conditions are very favorable. Relying on the rapid development of the surrounding economy, a large number of local and transshipmen container sources have been accumulated for the development of Taicang port. With 38.8 kilometers shoreline of the Yangtze River and 25.7 kilometers deep water shoreline, Taicang port has natural conditions of flat beach, stable boundary beach and near shore deepwater channel, which is very beneficial for the construction of the third and fourth generation container terminals, and is one of the best ports to meet the large scale of container ship type after the completion of the Yangtze Estuary Deepwater Channel.

Figure 2.2:The port and channelcondition of Taicang Port

2.3 Port planning

"General planning of Taicang port" has a clear positioning for the development of Taicang port. As an important part of Shanghai international shipping center,the competitive core port of Suzhou City, the important node of The Yangtze River Delta region of iron ore and coal into the river transportation system, and the port industry development in Taicang City is a key. The main function of Taicang port contains: focus on the service object of Suzhou City, Jiangsu Province, as well as the entire region along the Yangtze River, mainly in container, coal, iron ore and petrochemical transit storage and transportation, and provide key services for the development of port industry in Taicang City.

Figure 2.3:The port planning of Taicang Port

Taicang port area is divided into 5 working areas in the planning:

2.3.1 Lu He operation area: mainly provide service for the development of

equipment manufacturing and other port industry, with a natural coastline of 3.3 kilometers.

2.3.2 New Jing operation area: mainly provides service for container transport, as well as part of the grocery transport function, with a natural coastline of 4.6 kilometers.

2.3.3 Dang Qian operation area: large-scale bulk operations, mainly provides service for the iron ore and coal transportation of the Yangtze River, with a natural coastline of 3.7 kilometers.

2.3.4 Fu Qiao operation area: the special operation area for container transportation, with a natural coastline of 10.5 kilometers.

2.3.5 Qian Jing operation area: mainly provides service for the petrochemical, electric power, papermaking, equipment manufacturing, with a natural coastline of 6.1 kilometers.

In accordance with the "general rules" of the Taicang port layout planning, Taicang port plans to use the port coastline of 28.2 km. It can build 163all kinds of productive berths, including 76 One-million ton berths and 48 container berths, with more than 3 tons per year of the goods transportation capacity and 2147 million TEUs per year ofcontainerhandling capacity.

2.4 Pier and ancillary facilities

At present, Taicang Port has built a relatively complete system for transferring goods,

with a total of 72 quay berths, which includes 34 million-ton berths. Classification by types, there are 10 container berths, 16 bulk cargo berths, 17 liquid chemical berth, 23 dry bulk cargo berths and 6 other berths. The design throughput capacity is 1.25 million tons and 435 million TEUs, and Container lines has reached a total of 166, including 17 near-sea routes, 38domestic routes, 71Yangtze River lines and 40 Yangshan branch lines. (Liu, 2015)

As the multifunctional transportation terminal, Taicang port includes comprehensive bonded zone, information centre, port centralized inspection center, national timber import quarantine treatment zone, public dangerous goods container operation area, anchorage, regulatory assistance base, and a truck parking lot.

2.5 General of goods

There are many kinds of goods in and out of Taicang Port, including bulk cargo, bulk liquid cargo and container transport. The inward cargoes include metal ores, coal, oil, wood, chemical raw materials and products (mainly ethylene glycol, PTA), refined oil, sand and stone material and container goods, while the outward goods include metal ore, coal, chemical raw materials and products (mainly for ethylene glycol and PTA), refined oil, and container goods.

According to statistics (need source), in 2015 Taicang port cargo throughput reached 203 million tons, up 29.75%, and container throughput reached 370.61 million TEUs, with an increase of 21.24%. The throughput of large comprehensive cargoes increased significantly. In particular, iron ore and timber throughput ware a record high, and Taicang has became the largest import timber port in China.

2.6 Overview of ship in and out of Taicang Port

Located in the tail of the Yangtze River estuary, Taicang Port is the necessary channel for ships to go in and out of the Yangtze River. As a transit port in inland waterway, there is huge number of ships in Taicang port. Special geographical position means various types of ships with different sizes passing through or in and out of the waters of Taicang port. According to the local maritime agency statistics, in 2015, the number of ships in and out of Taicang port ship reached more than 100 thousand, with an increase of 20.24%. Also according to the 72 hour continuous ship traffic observation data from local maritime agency in 2015, the average ships passing Taicang harbor was more than 1000 per day.

As an integrated port, the types of ship passing through or in and out of Taicang Port include dry bulk carrier, container ship, bulk chemical tanker, oil tanker, LPG ship,fishing boat, steam passenger ferry , engineering vessel involved in construction, and floating crane ship. In addition, there is a certain number of offshore oil and gas platforms passing Taicang Port every year. In consideration of the huge number of ships including inland ship, coastal vessel and international ship, there is no doubt that the ship's pollution prevention management will be faced with great risks and difficulties in supervision.

2.7 Main risk sources

At present, there are two water intakes of fresh water reservoir in Taicang port, with water storage capacity of 4 million 500 thousand square and 14 million 720 thousand square respectively. The two water intakers are the main source of drinking water for millions of residents in Taicang City. Baoshan reservoir, one of the major sources of

water in Shanghai city, is not far from the downstream of Taicang port, which means that once a major pollution accident occurred in Taicang port, the residents of Taicang and Shanghai will face a great risk of drinking safety, and easily lead to large-scale social panic.

Figure 2.4:The water intake of water source in Taicang Port

Based on the comprehensive analysis of the present condition of the ship and the port of Taicang port, this paper puts forward the following main risk sources.

2.7.1 The risk of crew quality

The knowledge level of the inland river crew is generally low and influenced by the traditional customs and economic interests. Most of the crew lack the awareness of environmental protection and do not pay enough attention to the ship pollution

prevention work, and some crew members even do not know the seriousness of the pollution of the water environment. Although there are qualified anti-pollution equipment on some ships, these devices are not regularly used and maintained ed.

2.7.2 The risk of ship and terminal facilities

At present, the majority of ships in Taicang port have not installed sewage treatment equipment, and the majority of domestic sewage directly discharged into the inland water.

For the Dangerous goods transport terminal in Taicang port, the majority of docks are not equipped with the corresponding receiving equipment, or the facilities do not meet the requirements. Or, even the anti pollution receiving facilities are equipped, the terminal operators do not properly use these facilities.

2.7.3 The risk of toxic and hazardous goods

There are a large number of toxic and hazardous dangerous goods entering, departing or passing Taicang every year. In 2015, the number of ships in and out of Taicang port is more than 100000. Among them, more than 5000 ships are liquid cargo ships. The bulk liquid dangerous goods import and export volume of more than 750 tons per year, and the packaging category of toxic and hazardous dangerous goods reached 550 thousand tons. More noteworthy data is that the number of dangerous chemicals passing Taicang port each year reached 120 million tons.

CHAPTER 3

Analysis on Risk Factors of Ship Pollution in Taicang Port

3.1 Analysis and selection of ship pollution risk assessment index

It is a complex and comprehensive work to evaluate the environmental risk of ship pollution in inland waters, and various factors need to be taken into account, such as the meteorological and hydrological conditions, the traffic safety condition, the physicochemical and characteristics of goods, and the ship condition. Therefore, this work needs to be carried out by means of a complete evaluation index system. In order to play an early warning and guiding role to control the ship pollution in Taicang Port, this paper intends to analyze the various factors that may lead to the ship pollution in the area of Taicang Port and form a risk assessment system.

According to the International Maritime Organization marine oil spill risk assessment manual, one of the main purposes of risk assessment is to evaluate the adequacy of preparation and the ability to respond to the risk. By using the system risk assessment, it can be found in which areas of intervention will be more effective, thereby reducing the possibility of special events or event consequences. In this paper, the International Maritime Organization marine oil spill risk assessment manual (issued by IMO) and Technical specification for marine environmental risk assessment of marine pollution(issued by MOC) are used for reference for the establishment of Taicang port ship pollution risk system. At the same time, some of the indicators are adjusted according to the actual situation of Taicang port, and the multi-level analysis method is adopted to form a multi-level evaluation system according to the opinions of the maritime department.

3.2 Influencing factors of risk assessment

3.2.1 Navigation environment factors

(1) Hydrological and meteorological condition

In the operation of ships, the wind acts on the ships to generate a certain force, which is called the wind power. Wind power is the aerodynamic pressure on the part of the ship above the surface of the water when the ship is in a state of motion. Under the influence of wind, the ship speeds up when following wind and speed down when heading wind. When the ship sides surfaces wind, the bow will turn windward or leeward and leeward drift. According to statistics, the number of accidents related to wind speed in the unit observation time and the wind speed is of linear correlation (Zhang, 2005).

The navigation and operation of the ship is greatly influenced by the water flow and tide. If the ship speeds up and its angle cannot be controled appropriately, especially under the condition of the rapid flow, the ship moves very quickly and is very easy to cause collision accidents. In addition, when the ship is affected by the current, the track zone will become wider. The occupation of a wider channel in inland waters with high traffic density will also increase the risk of collision.

Ship collision, grounding and other accidents are easy to happen in fog, haze, snow and other low visibility conditions. According to the analysis on the Yangtze River navigation accidents, the safety of ship's navigation will be certainly affected under the condition of visibility less than 4 kilometers, and when the visibility is less than 1

kilometers, there is no guarantee for the safety navigation of the ship. In addition, the condition of the water depth in the channel or water area is also an important factor affecting the safety of the ship (Fan, 2006)

(2) Channel condition

Channel conditions mainly refer to the width of the channel and the maintenance depth, waterway straightness, other auxiliary navigation equipment and other natural conditions. There are many factors that affect the channel, for example, the channel twists and turns, change direction, shoal, rapids, as well as some navigation obstruction including shipwrecks, etc.

(3) Traffic density

The traffic density is the number of ships or fleet of ships that pass through a point in the water in a certain period of time. If the traffic density is bigger, the channel is more crowded, and ship collision accidents will more likely take place. Therefore, the traffic density has a great influence on the safety of ship navigation.

(4) The anchorage and berthing zone

Anchorage is a port in the waters for the safety of the ship anchorage, shelter, customs inspection, quarantine, loading and unloading cargo, and lighterage operation (Wang, 2010). The anchorage area depends on the mooring way, the number of ships and scale, wind and velocity.

The anchorage of Taicang port and berthing areas are set on the north side of the

main channel, not occupying the main channel or affecting the loading and unloading of the docks and the berthing or unberthing of ships. According to the types of anchored vessels, there are respectively dangerous goods anchorage, sea vessel anchorage, Liuhe anchorage and three temporary anchorage zone. As the Taicang Port is the first inland waterway port of the Yangtze River, there are a large number of ships in Taicang anchorage zone every day, which means that the vessel density in anchorage zone is far greater than the navigable channel. Therefore, the risk of ship pollution accidents is higher.

3.2.2 The factors of ship, port and cargo

(1) Ship factor

Ship type is based on the use of the ship, the ship tonnage, the scope of the ship's sailing and other factors. The same ships have different types according to the different ways of classification. The risk of ship pollution caused by oil tankers, chemical tankers and other dangerous goods ships is much higher than that of general cargo ships, container ships and passenger ships. Typically, the total tonnage represents a vessel size or operational capacity

Ship tonnage is a measure of the size of the ship, which can be divided into weight tonnage and volume tonnage. The ship's tonnage indirectly affects the risk of ship pollution by affecting the operational performance of the ship. According to the statistics and analysis of the related accidents, the tonnage and the degree of pollution risk of the ship are as follows：

Table 3.1: Grade tonnage & risk factor

Total Tonnage	Rank	Risk
500 below	Small-sized ship	Very Low
500-3000	Middle-sized ship	Low
3000-20000	Large-sized Ship	General
20000-100000	Huge-sized ship	High
More than 100000	Super large-sized ship	Very High

Ship age is the age of the vessel used for calculation of the ship's construction. Although the influence of the age of ship on the ship's pollution accident cannot be clearly explained, the industry consensus is that the greater the age of the ship, the greater chance to occur a ship accident. Taking into account the aging of the equipment and backward technology, the pollution accident occurred will cause greater harm.

The condition of the ship mainly refers to the technical condition, including course keeping performance, turning ability and stopping performance. In general, the higher the state of the ship's technology,maneuverability, andthe higher degree of automation, the stronger the ability to avoid accidents and pollution.

The quality of the crew is very important to the safety of navigation. Almost all accidents are caused by human factors. Crew factors can be divided into business ability, physical condition and sense of responsibility. Business ability includes the crew's degree, qualifications, professional knowledge and operational skills; physical condition includes fatigue, health status, and emotional. The sense of responsibility includes the professional ethics and work attitude. Crew quality not only affects the safety of ship navigation, but also reflects in the man-made emissions of pollutants,

including the marine oil sewage, shipdomestic wastewater, ship garbage and other pollutants.

(2) Port factor

The number of dangerous goods ship and dangerous goods cargo throughput directly reflects the busy degree of the dangerous goods operation in the port. It can be said that the more number of dangerous goods docks and dangerous goods berths in port, the more dangerous goods, and the higher the number of ships, the higher the probability of occurrence of pollution accidents.

(3) Wharf factor

The main function of the freight terminal is to load and unload cargoes. According to the statistics of the competent authority, nearly eighty percent of ship pollution accidents along the Yangtze River is the operation of the oil spill accident, and the terminal and its leading edge water area is the most area of the oil spill accidents. Therefore, the ship's pollution accidents, especially the operation oil spill accidents, greatly affected by the operating conditions of the pier. For example, the terminal equipment is advanced and reliable, liquid hazardous chemicals loading and unloading facilities are in good condition and oil spill reception facilities and equipment is complete.

(4) Cargo factor

Compared with the ordinary goods, the risk of water pollution is affected by a large number of vessels carrying dangerous goods. The ship carrying or handling

dangerous goods includes oil and dangerous chemicals, and also includes the container shipping and packaging of dangerous goods and bulk liquid dangerous chemicals. The greater the proportion of dangerous goods, the greater the risks of leakage.

3.2.3 Safety management factors

(1) Maritime safety supervision

The maritime competent authority is responsible for the safety supervision and prevention of water pollution caused by ships. As the main force of environmental supervision and management, whether the maritime authorities can effectively perform their duties to a certain extent affects the security situation. The ability to reflect the maritime safety supervision indicators include the number and level of maritime officers, the coverage area and cruise time of coastal patrol vessel and VTS monitoring ability, etc..

(2) Terminal company management

The management level of the wharf company also directly affects the probability of ship pollution accidents in the harbor. Many management deficiencies may cause the ship pollution accidents, such as the terminal manager cannot fulfill the function of safe production management, the terminal staff are lack of safety awareness or cannot strictly enforce the rules of operation, or the terminal and the ship are lack of effective communication and coordination.

3.3 Establishing of evaluation system

In reference to "technical specification for marine environmental risk assessment of marine pollution (for Trial Implementation)", "risk assessment index system" in Appendix 6.3.1, after screening, the risk evaluation system of 4 levels and 28 indicators system is formed, as shown in the following table.

Table 3.2: The risk evaluation system

goal level （A）	Standard level （B）	Index level I(C)	Index level II(D)
Environmental risks of ship pollution	Navigation environment factors (B1)	Hydrological and meteorological condition (C11)	Strong wind and typhoon (D111)
			Poor visibility (D112)
			Tide and current (D113)
		channel condition (C12)	width (D121)
			Depth (D122)
			Navigation obstruction (D123)
		Traffic density (C13)	Traffic Flow (D131)
			Dangerous goods ship flow (D132)
		The anchorage and berthing zone (C14)	Anchorage type (D141)
			Anchor density (D142)
	the factors of ship, port and cargo (B2)	Ship factor (C21)	Ship type (D211)
			Tonnage of ship (D212)
			Age and condition of ship (D213)
			Crew quality (D214)
		Port factor (C22)	The number of ships in and out of

			port (D221)
			The number of dangerous goods ship in and out of port (D222)
			The volume of of dangerous goods in and out of port (D223)
		Wharf factor (C23)	Wharf type (D231)
			Conditionsfor safe operation (D232)
			Receiving facilities (D233)
		Cargo factor (C24)	The hazard of Goods (D241)
			Single vessel traffic volume (D242)
	Safety management factors (B3)	Maritime safety supervision (C31)	Maritime officers (D311)
			Cruise time (D312)
			VTS monitoring ability (D313)
			The implementation of the fixed line system (D314)
		Terminal company managem ent (C32)	The professional proficiency of wharf staff (D321)
			Rules,regulations and Implementation (D322)

The first level is the target level, which is the overall objective of the risk assessment system. This paper will focus on the environmental risks of the marine pollution in Taicang port, discuss the possible risk factors and make a comprehensive evaluation.

The second level is the evaluation standard level. Because the ship pollution risk assessment index system is composed of many interrelated factors, it is relatively complex, so it needs to be divided into several categories of evaluation criteria.

The third and fourth level are the evaluation index factors, and each category of evaluation criteria level index should be refined in this level. Describe all quantitative and qualitative indicators to meet the requirements of the relevant data and information processing requirements of the follow-up evaluation model, and get the lowest evaluation index, and then follow the same steps and requirements for each of the major categories of indicators to carry out the above operation.(Hu, 2006)

3.4 Risk assessment index weight calculation

After the establishment of the above risk assessment system, the first step of the comprehensive evaluation of risks is to determine the weight of the risk factors of ship pollution, then give the evaluation criteria for each index and score, so as to obtain the comprehensive evaluation results.

Taking into account the types and characteristics of the various indicators are not the same, this paper mainly adopts the methods of expert investigation. There are 25 questionnaires completed by means of questionnaires to the maritime experts and complete the survey.

Based on the relative importance of the experts to give a comprehensive judgment, and based on the table given the assignment, and this paper then comes to Taicang port ship pollution risk comprehensive evaluation.

3.4.1 Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a relatively simple method to make decision for some complex and fuzzy problems and is particularly suitable for those problems that are difficult to be fully quantified. By applying the method of quantitative and qualitative comprehensive analysis, the decision maker can decompose the complex problem into several levels and a number of factors, and then make a simple comparison and calculation among the various factors to get the weight of different schemes,and provide the basis for the selection of the best program.

3.4.2 The main steps of AHP

The main idea of analytic hierarchy process is that: establish a multi-level structure model; compare elements of the same level, and determine its relative importance according to the criterion of judgment in order to establish judgment matrix; Through a certain calculation, determine the relative importance of each factor, which is called weight.

Analytic Hierarchy Process is a commonly used method to determine weight, including establishing hierarchical structure model, constructing judgment matrix, calculating single ordering weight value and the consistency check, calculate the

total sequencing weight value and the consistency check, and the specific steps are as follows:

(1) Analyse the relationship between the factors in the system, determine the objectives and evaluation factors, and establish the hierarchical structure of the system.

(2) Establish the judgment matrix based on an upper layer of elements as the judgment criterion, and do a comparison of the elements of the next layer, so as to determine the value of the elements of the judgment matrix. Scale method is used to compare the results, as shown in the table:

Table 3.3: Judgment matrix annotation and its implication

Serial number	Importance level	Index assignment (C_{ij})
1	i,j equally important	1
3	i significantly more important than j	5
5	i more important than j	9
7	i significantly not important than j	1/5
9	i not important than j	1/9

It is worth noting that, $C_{ij}=\{2,4,6,8,1/2,1/4,1/6,1/8\}$, indicates the importance level is situated between $C_{ij}=\{l,3,5,7,9,l/3,l/5,l/7,l/9\}$.

According to this table, we can get the judgment matrix of the same hierarchy index

A_{mm}, $A=\{a_1,a_2,\ldots,a_m\}=(a_{ij})_{mm}$.

the nature of A is as follows:

$$①\ a_{ij}>0 \quad ②\ a_{ij}=\frac{1}{a_{ij}} \quad ③\ i=j\text{时},\ a_{ij}=1$$

(3) The relative weight of each criterion is calculated by comparing the matrix, and the characteristic root and characteristic vector of the matrix are obtained. This feature vector is the importance ranking of the evaluation factors. after that, the consistency test of judgement matrix is done.

(4) the combined weight of the target layer to the total target and the consistency test is calculated, and get the weight of each index to the total target.

3.4.3 Consistency check

Due to the use of the multiple index comparison, it is necessary to determine the consistency of the group after the determination of the relative weight of the calculation.

The consistency index of the matrix is denoted as CI:

$$CI=\frac{\lambda_{\max}-n}{n-1}$$

$$CR = \frac{CI}{RI}$$

RI is the average random consistency index. The order of the matrix is different, and the value of RI is also different. RI values see table below:

Table 3.4: The value of the average random consistency index

Matrix order	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

When the CI is less than 0.1, the judgment matrix is obtained by the consistency test. Otherwise, re-construct the judgment matrix is needed.

3.4.4 Calculation method in this paper

Instead of fully using the above basic steps and afterthe establishment of risk assessment system, the research methods of expert scoring method and analogy method are mainly used in this research.

Firstly, the proportion criteria and weight judgment matrix of evaluation factors of ship polluted in Taicang Port can be acquired by scoring relevant experts of MSA. Then the author uses the analytic hierarchy process (AHP) software Yaahp (Yet Another AHP) to construct the hierarchical model and calculate. The software is able to provide the convenience of the hierarchy model structure, the judgment matrix

data entry, the sorting weight calculation and the calculation data export. Finally the author obtains the weight value of each layer of the evaluation factors, and then sort the basic risk factors of the ship pollution in the waters.

3.4.5 Construct comparison matrix

According to the above method, the comparison matrix of the same hierarchy is constructed, and the detailed information of each matrix is shown in table 3.5.

Table 3.5: Comparison matrix table

(a) total criterion layer comparison matrix

	B1	B2	B3
Navigation environment factors B1	1	1/4	1/2
the factors of ship, port and cargo B2	4	1	2
Safety management factors B3	2	1/2	1

(b) Comparison matrix of navigation environment factors

	C11	C12	C13	C14
Hydrological and meteorological condition	1	3	1	4

C11				
Channel condition C12	1/3	1	1/3	1
Traffic density C13	1	3	1	4
The anchorage and berthing zone C14	1/4	1	1/4	1

(c) Comparison matrix of ship, port and cargo

	C21	C22	C23	C24
Ship factor C21	1	5	3	2
Port factor C22	1/5	1	1/3	1/2
Wharf factor C23	1/3	3	1	1
Cargo factor C24	1/2	2	1	1

(d) Comparison matrix of Safety management factors

	C31	C32
Maritime safety supervision C31	1	1
Terminal company management	1	1

C32		

(d) Comparison matrix of hydrological and meteorological conditions

	D111	D112	D113
Strong wind / Typhoon D111	1	3	5
Poor visibility D112	1/3	1	2
Tide and current D113	1/5	1/2	1

(e) Comparison matrix of Channel condition

	D121	D122	D123
Width D121	1	5	3
Depth D122	1/5	1	1/2
Navigation obstruction D123	1/3	2	1

(f) Comparison matrix of Traffic density

	D131	D132
Traffic Flow D131	1	1/3
Dangerous goods ship flow D132	3	1

(g) Comparison matrix of the anchorage and berthing zone

	D141	D142
Anchorage type D141	1	1/4
Anchor density D142	4	1

(h) Comparison matrix of ship factor

	D211	D212	D213	D214
Ship type D211	1	3	1/4	1/4
Tonnage of ship D212	1/3	1	1/5	1/5
Age and condition of ship D213	4	5	1	1
Crew quality D214	4	5	1	1

(i) Comparison matrix of port factor

	D221	D222	D223
The number of ships in and out of port D221	1	1/3	1/5
The number of dangerous goods ship in and out of port D222	3	1	1/2
The volume of of dangerous goods in and out of port D223	5	2	1

(j) Comparison matrix of wharf factor

	D231	D232	D233

Wharf type D231	1	1/5	1/3
Conditionsfor safe operation D232	5	1	3
Receiving facilities D233	3	1/3	1

(k) Comparison matrix of cargo factor

	D241	D242
The hazard of Goods D241	1	4
Single vessel traffic volume D242	1/4	1

(l) Comparison matrix of Maritime safety supervision

	D311	D312	D313	D314
Maritime officers D311	1	1/5	1/4	1/4
Cruise time D312	5	1	2	2
VTS monitoring ability D313	4	1/2	1	1
The implementation of the fixed line system D314	4	1/2	1	1

(m) Comparison matrix of Terminal company management (C32)

	D321	D322

The professional proficiency of wharf staff (D321)	1	1/3
Rules,regulations and Implementation (D322)	3	1

3.4.6 Analysis

Table 3.4 is the comparison matrix in the parameters of the input level analysis of the software Yaahp, and the final weight of the factors table refer to table 3.5

Tab. 3.6 The final weight table

Goal level	Standard level	Weight value	Index level I	Weight value	Index level II	Weight value
Environmental risks of ship pollution	Navigation environment factors	0.143	Hydrological and meteorological condition (C11)	0.055	Strong wind and typhoon (D111)	0.036
					Poor visibility (D112)	0.013
					Tide and current (D113)	0.007
			Channel condition (C12)	0.017	Width (D121)	0.011
					Depth (D122)	0.002
					Navigation obstruction (D123)	0.004
			Traffic density (C13)	0.055	Traffic Flow (D131)	0.014
					Dangerous goods ship flow (D132)	0.042
			The anchorage and berthing zone (C14)	0.015	Anchorage type (D141)	0.003
					Anchor density (D142)	0.012
	the factors of ship, port and cargo	0.571	Ship factor (C21)	0.279	Ship type (D211)	0.037
					Tonnage of ship (D212)	0.019
					Age and condition	0.119

					of ship (D213)	
					Crew quality (D214)	0.119
			Port factor (C22)	0.052	The number of ships in and out of port (D221)	0.006
					The number of dangerous goods ship in and out of port (D222)	0.016
					The volume of of dangerous goods in and out of port (D223)	0.030
			Wharf factor (C23)	0.121	Wharf type (D231)	0.019
					Conditionsfor safe operation (D232)	0.077
					Receiving facilities (D233)	0.032
			Cargo factor (C24)	0.120	The hazard of good s (D241)	0.096
					Single vessel traffic volume (D242)	0.024
	Safety managemen t factors	0.286	Maritime safety supervision (C31)	0.143	Maritime officers (D311)	0.010
					Cruise time (D312)	0.063

					VTS monitoring ability (D313)	0.035
					The implementation of the fixed line system (D314)	0.035
			Terminal company management (C32)	0.143	The professional proficiency of wharf staff (D321)	0.036
					Rules,regulations and Implementation (D322)	0.107

CHAPTER 4

Main Problems of Ship Pollution Control in Taicang Port

4.1 Main risk factors and ranking

According to Table 3.5, the ship factor is the most influential factor among all the factors of ship pollution in Taicang harbor. Among all the ship factors, the age and condition of the ship and the quality of the crew is the most influential factor. The second most influential factor is the maritime safety supervision and enterprise security management. Among all the factors of maritime safety supervision, the cruise time of coastal patrol vessel is the most influential factor, and among all the factors of terminal company management, the weight of rules, regulations and implementation is biggest. The third influential factor is the influence of the wharf and cargo factors. Among them, the weight of the hazard of goods and conditions for safe operation are biggest.

Compared with the four factors mentioned above, other factors that affect the ship's pollution are less influential. According to the different weights, the main risk factors are listed in table 4.1.

Table 4.1: The sortedlist of the main risk factors

goal level	Index level I	Weight value	Index level II	Weight value
Environmental risks of	Ship factor	0.279	Age and condition of ship	0.112

ship pollution			Crew quality	0.112
	Terminal company management	0.143	Rules,regulations and Implementation	0.107
	Cargo factor	0.120	The hazard of goods	0.096
	Wharf factor	0.121	Conditions for safe operation	0.077
	Maritime safety supervision	0.143	Cruise time	0.067

4.2 The problems of ship's age and condition

Most of the ships passing through and entering and leaving Taicang harbour are inland waterway vessels. Among inland waterway vessels, the main engine of the ship is mainly used for diesel engine, and the cargo oil types ship loaded include gasoline, diesel oil, sludge, oil residue and other refined petroleum products and the oil products used in the operation of the ship's main engine, for example, fuel oil and lubricating oil. When the ship spills oil sewage and oil, the river water will be polluted.

Inland waterway ship pollution not only contains the pollution of oil pollution, but also contains toxic liquid pollution, hazardous substances, the pollution of domestic sewage and solid waste pollution. According to the requirements of the Ministry of Communications of China "inland river ship anti pollution structures and equipment standards", at present, most of the inland river ship has installed oil-water separator or oil sewage tank, which is used to handle or store ship oil wastewater. In recent years, a large number of the ship's actual survey shows that many of the ship's oil

water separator usage does not meet the requirements. Because of the high maintenance cost, the oil pollution treatment equipment is often in idle state, and some of the ships secretly discharged sewage when sailing at night or out of port.

Although MARPOL 73 / 78 of Annex IV of the Convention "to prevent ship domestic sewage pollution rules" has taken into force in February 2007, domestic ship installation of sewage treatment equipment requirements apply only to new vessels. At present, the majority of ships in Taicang Port have not installed sewage treatment equipment, and the majority of domestic sewage is directly discharged into the inland water.

4.3 The problems of crew quality

The knowledge level of the inland river crew is generally low. Most of the inland water ships in Taicang harbor are small and medium sized ships, and most of them do not have anti-pollution treatment equipment. Influenced by the traditional customs and economic interests, most of the crew are weak in the awareness of environmental protection and do not pay enough attention to the ship pollution prevention work, and some crew members even do not know the seriousness of the pollution of the water environment. Although there are qualified anti-pollution equipment on some ships, these devices do not regularly used and maintained. Some ships are equipped with the old technology of environmental protection equipment, which is useless and do not comply with the requirements.

For the majority of seagoing vessels from private shipping companies, the crew members are usually not graduated from a formal maritime university. Although the Senior crew have rich experience in navigation and high level of ship operation, they

are lack of the professional and systematic training about sailing knowledge and legal knowledge training, which lead to their low awareness of pollution prevention. Some ships do not comply with the provisions to discarded garbage, sewage and ballast water. In the process of supplying and receiving oil, dangerous goods loading and unloading operations and engine room maintenance, some crew are not strictly in accordance with the relevant anti pollution operating procedures, which has brought great hidden danger of pollution.

4.4 The problems of rules, regulations and implementation

In China, the standards of anti-pollution equipment for the inland river ships are relatively low. For dealing with domestic sewage and domestic waste, there are almost no corresponding treatment equipment configuration requirements, with only a rule of that it is not allowed to discharge into the water at will. The actual situation of Taicang port is indeed the case.

Recently, the Marine Department of Taicang port the ship carried out a survey about the use and equipment of the pollution prevention equipment, and the object of information collection are 200 inland river ships and 100 seagoing vessels in Taicang port. However, the findings are very disappointing and alarming. Almost all inland river vessels investigated are equipped with oil water separator, without other equipments for the treatment of domestic sewage and garbage disposal. While for almost seagoing ships, the use and equipment of the pollution prevention equipment can meet the requirements, and only a small number of seagoing ships' use rate is relatively low.

Mainly due to the depression of the shipping industry in recent years, a lot of

shipping companies are operating at loss. Ship owners do not want to cost too much in the ship equipment maintenance. In particular, they are not willing to spend money on maintenance of anti-pollution equipment, which does not directly relate to the safety of navigation of ships. In order to reduce the cost, some ships purchaseanti pollution equipment without product certificatation, or the certification does not match with the anti-pollution equipment.

4.5 The problems of the hazard of goods

With economic development of Taicang port, the container goods throughput increased rapidly with 370 TEU in 2015, in which the dangerous cargo container volume is also increasing year by year. However, due to the strong concealment of the transport form, it is difficult to find the behavior of concealing dangerous containers or lying for ordinary cargo containers, which cause great security risks to water transport, and pose a serious threat to the safety of ships, personnel, and water pollution.

In the maritime unpacking inspection, there are lots of problems. The consignor claims the dangerous goods falsely as ordinary goods, which brings great security risks for water transport. The agent fails to declare the dangerous goods in accordance with the regulations, which shows that their business quality and risk awareness needs to be strengthened. In addition, the inspection personnel also find kinds of unqualified defects, such as lack of packing, lack of dangerous goods marked ,liner is not qualified, binding is not strong, etc..

4.6 The problems of conditions for safe operation

According to statistics, nearly 90% of the inland waterway ports have not established effectively management facilities to receive and deal with the marine pollutants. Even if the inland waterway vessels installed oil-water separator, the oil pollutants separated in navigation cannot be received in many ports, and lack of follow-up facilities. Domestic sewage also did not establish a special pollution discharge channel, did not have plan to prevent the water pollution caused by the overturn of the ship, and lack of the facilities for handling the pollution accident of ships.

For the chemical terminal in Taicang port, the majority of docks are not equipped with the corresponding receiving equipment. Even part of the pier with sewage treatment facilities, the original intention is to meet the requirements of the environment department to deal with the waste water from washing tanks or flushing field, instead of using to receive and process the residue and mixture of oil washing tank waste water or toxic liquid substances discharged from the ship.

Due to the fact that the shore receiving system has not been established in Taicang port, the main way to deal with the solid waste in the harbor is to receive by a paid qualified company. This way leads to a very low rate of life garbage collection and treatment, and some ships escape paying and secretly dump.

4.7 The problems of cruise time

As the main force of water law enforcement in Taicang Port, the patrol officers from Taicang Maritime Safety Administration are responsible for the ships pollution control work in the Taicang section of the Yangtze River with 38.8 km coastline. But at the present stage, there are not enough resources to support the full time cruise and no blind spot monitoring requirements in Taicang port, no matter from the number of

law enforcement officers or the number and quality of the sea patrol boats.

Currently, a total of 13 law enforcement officers and 6 sea patrol boats are responsible for the water cruise law enforcement work. Among them, Sea Patrol 06860, Sea Patrol 06861 and Sea Patrol 06866are steel boats, and the other three are small glass craft. Although the glass boats have the characteristics of fast speed and flexible operation, they also have the disadvantages of poor wind resistance, which are severely restricted by weather conditions. Sea Patrol 06860 was built at the beginning of the last century in 90s, and the speed and equipment cannot meet the needs of the development of safe cruise. Sea Patrol 06866 is designed as clean-up boat and actually does not have the cruise function. In addition, the current law enforcement resources not only assume the responsibility of water on the cruise law enforcement, but also bear the task of searching for water in Taicang section of the Yangtze River.

Although maritime authorities had done a lot of work to prevent oil pollution, they did not get very good effect because of lacking professional equipment and comprehensive supervision. Obviously, traditional and passive management modes have no longer met the current situation of preventing pollution in Taicang Port.

CHAPTER 5

The Suggestion of Ship Pollution Control in Taicang Port

5.1 Strictly implement the environmental laws and regulations of ship pollution prevention and control

At present, the conventions, the laws and regulations relating to the prevention and control of the pollution from ships in China are the following: MARPOL 73 / 78, Law on the Prevention and Control of Water Pollution, Law of Ocean Environmental Protection, Law on the Prevention and Control of Air Pollution, the prevention of the ship breaking pollution control regulations, and the Regulations on the Prevention of Environmental Pollution by Ship Scrapping. In addition, there are some local regulations and rules, which also play a role in the prevention and management of the ship pollution. Although there are a lot of regulations to restrict the ship pollution, all relevant parties including maritime authorities, shipping companies and ships did not strictly enforce the rules, which result in that illegal emissions in Taicang port occured from time to time .

On the one hand, it is proposed that the maritime authority does an adequate research for the implementation of ship pollution prevention in Taicang port to know well the real situation, and then implement the supervisory responsibilities to the relevant departments, and develop a detailed inspection plan to promote the effective implementation of existing laws and regulations on pollution control in the ship.

On the other hand, it is recommended that the maritime authority actively communicate and cooperate with the customs, the immigration department and other

port units. According to the actual situation of Taicang port, the research and development of local pollution prevention guidance is very advantageous to prevent pollution in Taicang port.

In addition, from the Ministry of Transport, the newly revised "Regulations on environmental management of inland waters of the prevention and control of ship pollution" has been implemented since May 1, 2016. The new regulations have greatly improved the standards and requirements for the environmental protection of ships and their operations to inland waters, and put forward five specific requirements to prohibit the discharge. The first is to prohibit the discharge of toxic liquid substances and their residues or ballast water, washing water or other mixture containing such substances; the second is to prohibit the use of burning furnace; the third is to prohibit the use of oil spill dispersant; the fourth is to prohibit the discharge of marine refuse, and the last is the water pollutants produced in shipbuilding and related operations in the process should be promptly removed, prohibiting jettison into the water.

Since April 1, 2016, the Yangtze River Delta region will be the first to start the implementation of emission reduction. Ships in the waters of the Yangtze River Delta emission control area during the core port moored, the use of sulfur content is not more than 0.5% (M / M) of the fuel. These new rules provide an opportunity for Taicang port to establish and improve the ship pollution prevention system, and there is no doubt that positive measures should be taken to ensure the effective implementation of the new rules.

5.2 Establishing a detailed management system of publicity, training, inspection and evaluation

As the main body of ship anti-pollution, whether the shipping companies, ship owners and crew can consciously complete the pollution prevention task is the most critical and important. The maritime authority should carry out extensive publicity through various channels and help the shipping enterprises and the crew to fully realize the harmfulness of pollution from ships.

Secondly, according to the actual situation of the dangerous goods transportation companies and the dangerous goods transport ships in Taicang Port,主语 to establish the detailed and practical training plan, including the training of laws and regulations and the guidance of the practical operation ability. The most important section is to effectively help the crew to improve the ability to prevent pollution. In particular, when the ship pollution accident occurs, it should be ensured that the crew can quickly and effectively carry out oil pollution emergency control and prevent the spread of oil spills at the first time.

Finally，the actual operation ability of crew for the prevention of ship pollution is recommended to be the focus of the inspection content. According to the expert analysis, for the inland waterway transport safety issues, paying no attention to the inspection of the ship handling equipment and the actual operation ability of the crew are the important reasons for the accident of dangerous chemical transportation in inland waterway. Normally in the flag State supervision and inspection or special inspection, the law enforcement officers mainly check that the ship navigation equipment, the main engine power equipment, the fire and rescue equipment, and anti-pollution equipment are in good condition and can be used at any time, but rarely checking if the crew is able to use the equipment correctly, especially the correct use of anti-pollution equipment. By analyzing lots of accidents, it is found

that most of the pollution accidents are caused by the actual operation of the crew failed to meet the requirements, and the consequences are very serious.

5.3 The improvement of the port facilities and the capacity of terminal pollutant reception

According to the the size of the ship's import and export volume, the establishment of garbage collection and oil sewage receiving device is necessary in some large ship dock, water service area and anchorages. It is worth emphasizing that all anti-pollution facilities should be arranged in line with the characteristics of the waters of Taicang port. In addition to the increase of hardware input, it is very feasible to establish a complete system of supervision, restraint and reward. Only the fundamental control from the source of the spread of pollutants in the port can reduce the terminal front and the operation of the water pollution accident.

5.4 The establishment of professional emergency resource pool and emergency response team, and the improvement of the ability of accident prevention and emergency treatment

It is very important to focuse on the establishment of professional emergency resource base and emergency response teams, perfect the emergency disposal mechanism, and improve the ability to deal with emergencies, which should be suggested as a long and crucial task for the anti pollution of Taicang Port.

Emergency prevention mechanism and emergency response mechanism are both very important. Emergency prevention mechanism is to ensure effective emergency response and the measures taken in advance, including the establishment of

professional emergency teams and regular exercise, emergency equipment maintenance and emergency members of the division of labor and cooperation, etc. When the oil spill accident occurs, the emergency response mechanism will play a huge role, which through the effective disposal and reduce harm to minimum, including alarm information, timely delivery, the start of the different disposal plan and emergency response teams and emergency equipment, pollution accident treatment and disposal etc.

CHAPTER 6

Conclusion and Prospect

Taicang port is facing the golden period of rapid development of port economy, but there are still some problems and deficiencies in the risk control of ship anti pollution, including the ship pollution prevention equipments noncompliance with requirement, the weak environmental awareness of crew, the poor actual operational capacity of pollution prevention, the inadequate terminal anti pollution receiving facility, and the lack of professional personnel and equipments resources for supervision and management. In view of the above actual problems, this paper did a theoretical analysis of the existing problems by deeply research so as to determine the main anti-pollution risk factors of Taicang port, and carried out a special study to put forward a reasonable and feasible risk solutions, including the strict implementation of the environmental laws and regulations of ship pollution prevention and control, the establishment of a detailed management system of publicity, training, inspection and evaluation, the improvement of the port facilities and the capacity of terminal pollutant reception, and the establishment of professional emergency resource pool and emergency response team, and improve the ability of accident prevention and emergency treatment.

Because of its special geographical position, the ecological environment of Taicang port has considerable impact not only upon the local development but also on the sustainable development of the whole Yangtze River basin. With the continuous innovation and progress of science and technology, in the near future, we can look forward to a full range of three-dimensional anti-pollution monitoring system. We must strive to achieve the goal of establishingrapid response mechanism based on the

professional cruising team, sea patrol vessels and marine helicopter in order to face the situation of oil spill and effectively protecting the water environment of Taicang port.

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