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Research on prevention of ship-induced pollution to drinking water source in the Yangtze Estuary of Shanghai Sector

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Dalian, China

Research on Prevention of Ship-induced Pollution to Drinking Water Source in the Yangtze Estuary of Shanghai Sector

By

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

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2015

DECLARATION

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

The contents of this dissertation only express my own personal opinions, and are not necessarily endorsed by the University.

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Title: **Research on Prevention of Ship-induced Pollution to Drinking Water Source in the Yangtze Estuary of Shanghai Sector**

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Abstract

The estuary of the Yangtze River is not only the busiest region for water transport in China, but also the most significant ecological protection area. In particular, several drinking reservoirs including Qingcaosha, Chen-hang and Dongfengxisha are located in this area, not far from the deep water channel. With the development of Shanghai port and ports inside the river, the density of vessel traffic will be further increased, as well as shipping demands for oil and bulk chemicals. Nonetheless, the frequently operational and accidental ship-induced pollution has brought huge risks to drinking water source. Therefore, the water source is facing great threats from ships' activities in water channels, anchorages and nearby shipyards. It is urgent and necessary to start the study on prevention of ship-sourced pollution, and find out effective measures to enhance the maritime supervision of anti-pollution from ships.

At first, this paper gives a brief introduction on the surrounding environment of drinking reservoirs, which includes water and wind conditions, nearby channels and shipyards around the water source. Subsequently, the items of ship-sourced pollution which poses high risks are identified by means of risk assessment. In addition, based on the author's work experience, difficulties lies in the prevention of ship-induced pollution to drinking water source and weaknesses of maritime supervision in this area have been analyzed in details. In order to solve these problems, the dissertation proposes some countermeasures to reduce the risk of pollution from ship and improve the performance of emergency response. Eventually, an opinion of establishing the ecological sensitive area of water source is proposed, and ships' activities should obey certain specific rules inside the ecological sensitive area, which is expected to have effects on protecting the drinking wellhead from ship-induced pollution.

Key Words: Ship-induced pollution, drinking water source, risk assessment, maritime supervision

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ABBREVIATIONS

AIS	Automatic Identification System
CCTV	Closed Circuit Television
FSA	Formal Risk Assessment
FSC	Flag State Control
IMO	International Maritime Organization
MARPOL73/78	International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978
MSA	Maritime Safety Administration
NWW	North-West-West
PRC	People's Republic of China
PSC	Port State Control
SHMSA	Shanghai Maritime Safety Administration
SOA	State Oceanic Administration
SSE	South-South-East,
SW	South-West
TSS	Traffic Separation Scheme
VTS	Vessel Traffic Services

Chapter I Introduction

1.1 Research Background

Water is the most important resource for the survival of life; drinking water as the basic human needs is becoming increasingly scarce. With the rapid development of China's economy and society, the safety of drinking water has been a widespread concern in the society. The General Office of the State Council of the People's Republic of China (2005) issued the Notification of the State Council on strengthening the safety of drinking water, calling for further consideration on the safety of drinking water source.

On February 3, 2012, due to the improper operation of unloading of dangerous goods, chemical tanker "FC GLORIA" flying South Korea flag leaked out 45 tons of phenol in Zhenjiang Port of Jiangsu Province. It brought serious pollution consequences to the Yangtze River; many cities built along and taking the drinking water from the Yangtze River had to shut down the water intakes of reservoirs, which caused mass panic and problems of social stability (Yang, 2014). On May 18, 2012, due to strong wind, the domestic oil tanker "SILVER 6" sank at Wusong anchorage in the estuary of Yangtze River, and the cargo oil leaked out. What is worse, by the effect of the storm and current, the spilled oil drifted to the Qingcaosha wellhead which is the biggest reservoir in Shanghai of China, supplying more than ten million of people with drinking water. The accident caused great concern of government of Shanghai and the general public. Fortunately, due to the well performance and effective measures of emergency response of the Shanghai Maritime Safety Administration (SHMSA) and relevant departments, Qingcaosha was not affected by the oil-pollution accident (Shanghai Municipal Transportation Commission, 2012). The incident once again sounded the alarm: the drinking water source shall be protected from ship-induced pollutions without delay.

The mouth of the Yangtze River is an environmental sensitive water area, which belongs to typical river estuary ecosystem. Nevertheless, in this area it also has the world's busiest ports block, the intensive ship traffic flow, and large number of building and repairing shipyards.

According to the Regulations on Drinking Water-source Protection of Shanghai City (2009), Qingcaosha, Chen-Hang and Dongfengxisha reservoirs which are all located in the of Yangtze estuary are designated as drinking water sources of Class-1 in Shanghai (Shanghai Municipal People's Congress, 2009). However, the reservoirs are adjacent to vessel navigable waters, and readily affected by the nearby ships' activities of navigation and repair, facing greater risk of ship-sourced pollution.

As the department in charge of water safety supervision, prevention and control of pollution from ships, Maritime Safety Administration has unshirkable responsibilities for managing the activities of water pollution caused by ships. This research paper intends to analyze and assess the risk of ship-induced pollution and point out the present situation and existing problems. Meanwhile, it puts forward the corresponding countermeasures to provide feasible references for the prevention and control of marine pollution to estuarine reservoirs.

1.2 Importance of the Study

The area of Yangtze River estuary is an important geographical position for Water transport. The shipping industry develops very fast in this region; also most of the ship building and repairing yards for large vessels clustered around this area. In addition, because of the high density distribution of large ports across the Yangtze River (Shanghai, Taicang, Nantong, Jiangyin, Zhenjiang, Nanjing, etc), ships entering and departing from the river have to pass through the channels in the estuary, resulting in this place the busiest fairway in China. The task of traffic management is arduous, despite the Traffic Separation Scheme (TSS) has been established since many years ago in the Yangtze Estuary, ship collision accidents still occur sometimes. Moreover, the pollutions caused by ship collision accidents are more harmful, for the damage is severer, and difficult to predict.

Meanwhile, the place is critically important in the national fishery resources and drinking water source protection. The ship-induced accidents of oil spill or dangerous chemicals leakage will undoubtedly cause great disaster to social economy, ecological environment and human life. Therefore, to carry out the identification and assessment of pollution risks, develop effective measures to prevent the ship-sourced pollution in this area and to protect the ecological sensitive area of drinking water source is particularly urgent and important.

1.3 Objectives of the Study

The objective of this research paper is to identify the risk level of ship-induced pollution through Formal Risk Assessment (FSA) in Yangtze River Estuary of Shanghai Sector, and finally find out some effective measures to supervise vessels threatening the water source protection zones. Meanwhile, the dissertation aims to improve the performance of SHMSA on protecting the drinking reservoirs from ship pollutions by means of establishing a water pollution monitoring, information tracking mechanism. Furthermore, some countermeasures to deal with operational risk and accidental risk of ship pollution will be proposed by this paper. There are some sub-objectives of study which include:

(1) To make up for the gaps of supervision and management of SHMSA, improve the ability and level of the safety management of the shipping activities, and provide references for the competent authorities to formulate relevant policies.

(2) To develop the risk assessment for pollution accident around the water source protection zones, explore effective management methods to control dangerous and high-risk operations of ships, and provide references for SHMSA to carry out the relevant approvals of hazardous operation.

1.4 Research Methodology

The main research methods of this paper include field survey, statistics and data analysis, comparison method, combination of theory and practice. Firstly, the author collects piles of data and through field investigation on reservoir managing company, shipyards and relevant departments of SHMSA, and carries out statistical analysis. Secondly, the paper refers to a large amount of others' research on preventing the ship pollution, and uses the theory of risk management to identify the high risk item of shipping activities in the area. Moreover, based on the author's 5 years experience of anti-pollution management in the Chongming Branch of SHMSA, the status quo of the water source ship-induced pollution prevention is summarized, and the weaknesses of maritime supervision are pointed out.

1.5 Layout of the Paper

There are six chapters in this dissertation. Chapter I introduces the background, importance, purpose and the methodology of the research. Chapter II gives an overview of water source protection area and the surrounding waters. Chapter III is significantly important; the author intends to identify the highest risks for the water source protection zone. Chapter IV summarizes the status quo of management on preventing and controlling the ship-induced pollution to water source, and finds out the weakness of maritime supervision. In Chapter V, the author will propose several effective countermeasures to reduce or eliminate risks of pollutions. And Chapter 6 is to draw the conclusion.

Chapter II Overview of Water Source Protection Area and Its Surrounding Waters

2.1 Brief introduction on drinking water source in Yangtze River Estuary

At present, totally three reservoirs are located in the Yangtze River Estuary of Shanghai sector; there are Qingcaosha, Chen-Hang and Dongfengxisha reservoir. These reservoirs are on the verge of a busy waterway-South Branch of Yangtze River. The geographical location is shown by **Figure 2.1**. The Qingcaosha reservoir is the largest drinking water source in Shanghai which was completed in 2010, occupying an area of about 70 square kilometers; the average annual runoff is about 933 billion cubic meters. It is a mid-river reservoir which supplies more than 60% of the raw water to Shanghai city (Wang, 2011, pp. 3-7). Chen-hang reservoir was built in 1980's at the junction of Liu River and Yangtze River. It is a river shoal reservoir, and the daily water supply capacity is about 180 million cubic meters. Dongfengxisha, the second mid-river reservoir with functions of storing fresh water and avoiding salinity, is located on the southwest of Chongming Island. It was put into use on January 17, 2014. The comparison of daily water supply capacity of three reservoirs is shown in **Table 2.1**.

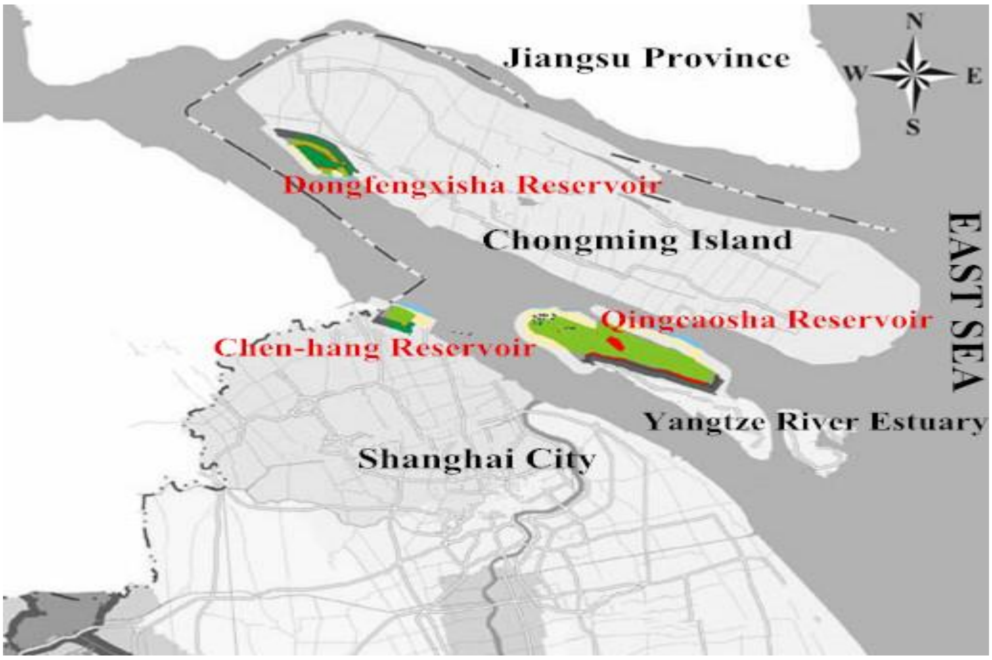

Figure 2.1: Location of drinking water source in Yangtze Estuary of Shanghai Sector

Source: Shanghai Environmental Protection Bureau, http://www.sepb.gov.cn

Table 2.1: Comparison of daily water supply of reservoirs

Reservoirs	Daily supply capacity (million cubic meters)
Qingcaosha	719
Chen-hang	180
Dongfengxisha	21.5

Source: Shanghai Water Authority

Figure 2.1 and **Table 2.1**show that from both the area and water supply capacity, Qingcaosha is the largest drinking water source protection area. Meanwhile, three reservoirs are close to each other, so this paper will take the waters around the Qingcaosha as the representative region for analysis. Qingcaosha reservoir has two open water intake, one is the upstream pump water gate, and the other is the downstream sluice. The main function of the upstream water intake pump gate is to obtain and store the fresh water by natural force of river current during non-salt tide period. During the salt tide period it takes fresh water timely through pumps to avoid being salty and achieves the goal of pre-storage of freshwater. In addition, it can be used to adjust the water lever for emergency, and link with the downstream sluice to ensure the quality of water to meet the requirements. Therefore, the water-intaking time is not fixed and it much depends on the water quality and water lever of reservoir.

In accordance with the Regulations on Drinking Water Source Protection Areas of Shanghai City (2009), the Class-1 protecting areas covers the water area inside the reservoir and waters 200m outside the boundary dam of reservoirs and 500m outside the intake water gate; the Class-2 protecting zone includes all waters 1700m outside the boundary dam of reservoir. However, two fairways go across the Class-2 Protection Zone. One is the Xinqiao Passage, transited by ships coming in and out of Chongming Island, with large ocean-going ships entering Dadong and Shanghai shipyards; the other is the North Port channel which is mainly used by dredging ships, sand-blowing and transport vessels, working boat and fishing vessels. Nonetheless, more importantly, there are many navigable waterways, ship building and repairing yards, dense water traffic even unpredictable ship accidents around the whole water region.

2.2 Brief information on surrounding waters of drinking water source

2.2.1 Conditions of waves and tides

Waves in the waters around Qingcaosha water source protection zone are usually wind-forced or wind and water current mixed. The main wave generally moves toward northwest. According to the statistics released by the hydrological station of Gaoqiao, the maximum wave height is 3.20m; the maximum wave cycle is 5.8s. The frequency is that 29.4% no waves, wave height less than or equal to 1m is 69.3%, and wave height over 1m is 1.3% (Fu, 2013). By the comprehensive analysis on wind and wave conditions of south branch of Yangtze River, the main wave directions around the reservoir most are South-South-East (SSE), South (S), South-West (SW) and North-West-West (NWW).

The tide in the estuary belongs to non-regular semi-diurnal tide; the highest tide level is 4.13m. The lowest tide is -0.25m. The tide brings fast water flows; the maximum flow speed is 1.81m/s, maximum ebb 1.51m/s (Shen, 2015).

2.2.2 Navigable waters in the vicinity of drinking water source

Qingcaosha Reservoir is surrounded by the navigable waters. The Xinqiao Channel and Xinqiao Passage are on the west of the reservoir; North Port Channel on the north; the North channel, South Channel, Waigaoqiao Fairway, Baoshan Fairway, and North Baoshan Channel are on the south; and Hengsha Passage on the east. The distribution map is shown in **Figure 2.2**, and the brief information of nearby waterways is illustrated in **Table 2.2**.

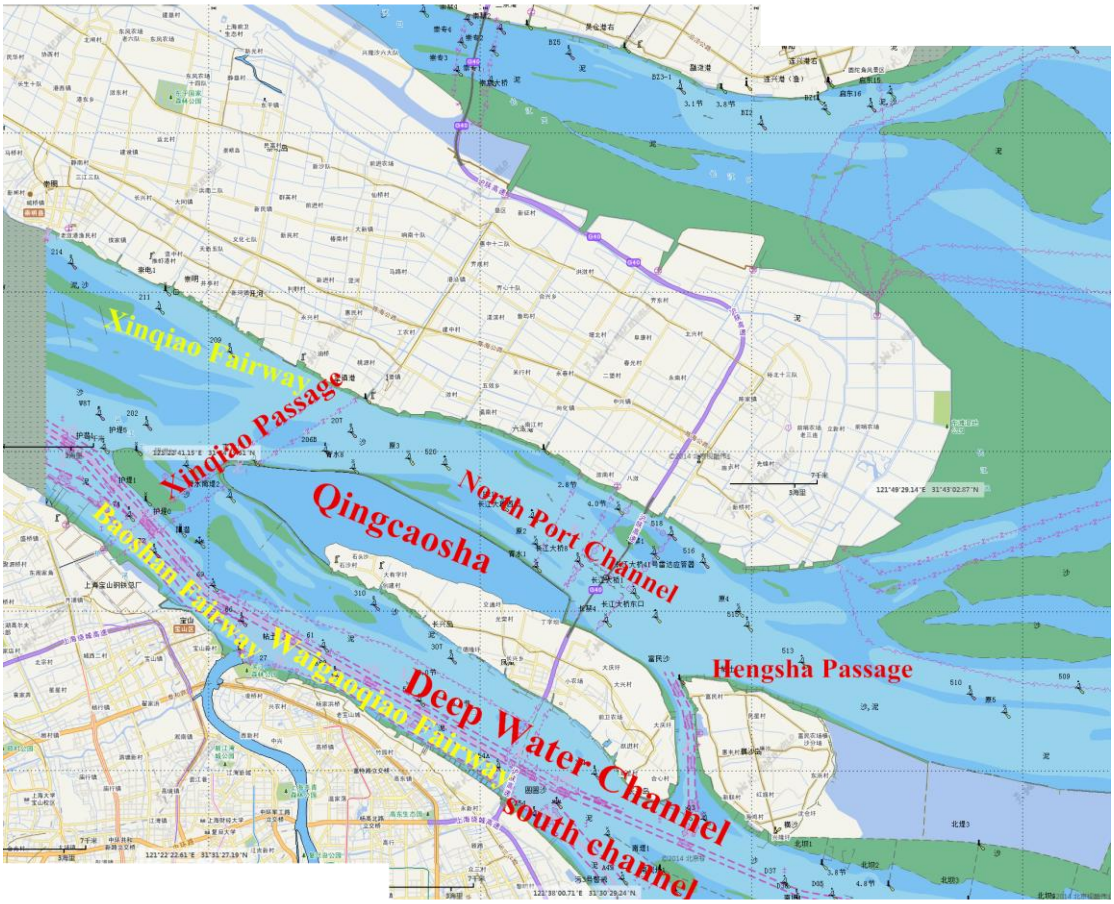

Figure 2.2: Distribution of navigable waters around Qingcaosha Reservoir

Source: http://map.baidu.com/, compiled by the author.

Table 2.2: Brief information of surrounding navigable waters

Fairways	Location and length	The passed Ships
Xinqiao Passage	from lighted buoy 67 to 207; 7.8nm	1,Ships come in and out of Dadong shipyard and Shanghai shipyard; 2, Ferries between Shanghai and Chongming Island; 3, Ships come in and out Chongming Island from the Yangtze River
Xinqiao Channel	On the southern coastal waters of Chongming Island, from floating light 207 to 215, 11.2nm. about 500 meters wide depth of 7 meters above	1,Ships come in and out of Dadong shipyard and Shanghai shipyard; 2, Ferries between Shanghai and Chongming Island; 3, Ships come in and out Chongming Island from the Yangtze River
North port channel	on the east of Bao town port and the southern coastal waters of Chongming Island, 7000m wide with length of 34.7nm	1,Dredging ship and constructing ship for transporting and blowing sands; 3,Small cargo ships come from Hengsha passage 4,A large number of fishing boats 5,Work ships joined Hengsha East Shoal reclamation project and river dam restoration project
South Changxing waterway	Waters between the South coastal of Changxing Island and Ruifeng sand. Starting form the H7 floating light to the northwest corner of Changxing Island; 11nm with a width of 300-1200 meters	1,Large crane shipS work for shipyard in Changxin 2, Large ocean-going ships come in and out of Changxing Island for repairing or new building ships; 3, The ferries come in and out of the island; 4, Working boats for surrounding projects
Hengsha passage	Connecting the north port channel to the north, deep-water channel to the south, length of 8432 meters, 800 to 1000 meters wide.	Small cargo ships enter Chongming water and small working boat or fishing vessels.
The South Channel	on the south costal of Yangtze river of Waigaoqiao section, about 17nm	1, Smaller ships enter or exit in Yangtze river; 2, Unload large ships with shallow draft. (traffic volume accounted: 70% of the total number of the Yangtze River Estuary navigation ships)
The North Channel	from the west side boundary line of the precautionary area A to the east boundary side of Yuanyuan sand precautionary area ,about 43nm, water depth has reached 12.5 meters	Only allow large ships to navigate
Waigaoqiao Fairway	from Yuanyuan sand lightship to Wusongkou, about 10nm long, width of 0.4 ~ 0.5nm, depth above 11.4m	Only allow large ships to navigate
Baoshan Fairway	South coastal water of Yangtze river of Baoshan section,6nm long;1000m wide;10m above deep	Only allow large ships to navigate

Source: SHMSA, compiled by the author.

2.3 Shipyards around the drinking water source

Many shipyards are distributed on the upstream and downstream of Qingcaosha Reservoir, on the upstream, there are Dadong ship repairing yard, Shanghai shipyard, Xinhua ship recycling yard; on the downstream the reservoir is close to the Changxing Shipbuilding Base, China-Shipping Shipyard, Zhenhua Port Machinery yard and Changxing dangerous goods dock. Large numbers of vessels come in and out of these shipyards for building, repairing and dismantling, and it brings the water high risk of pollution.

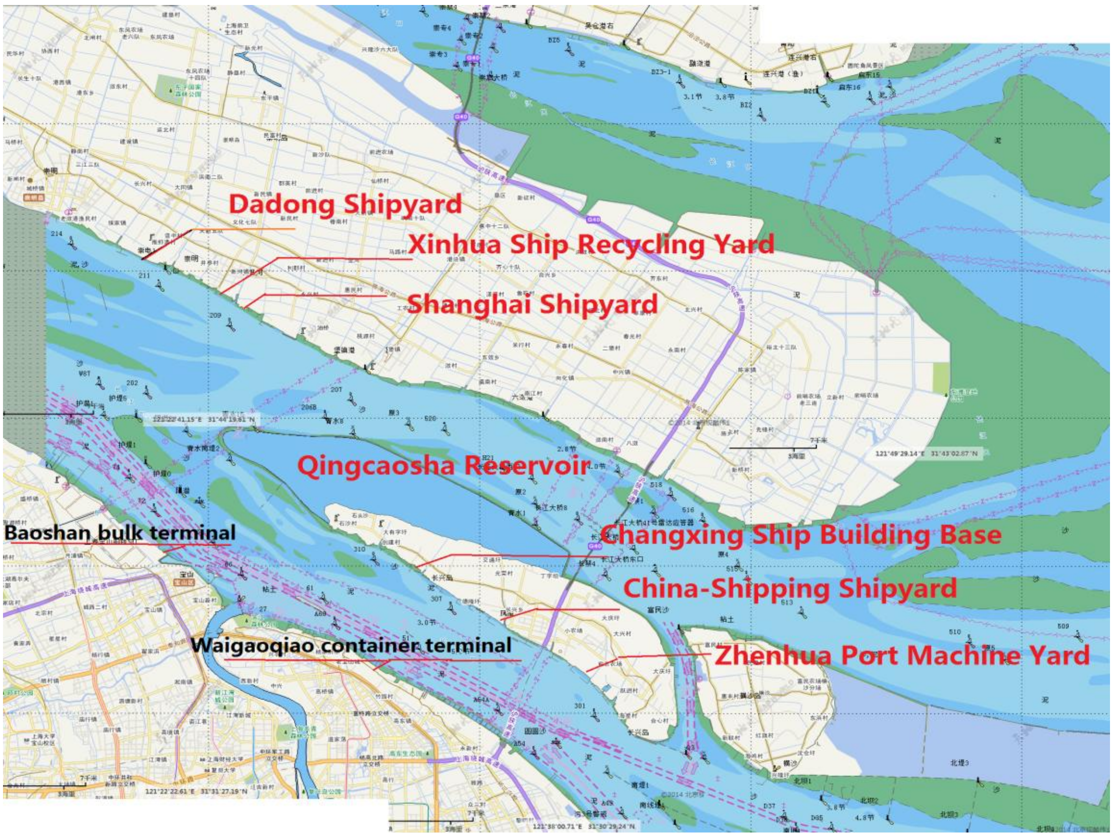

Figure 2.3: Distribution of shipyards around Qingcaosha Reservoir

Source: http://map.baidu.com/, compiled by the author.

Table 2.3: Brief information of shipyards around Qingcaosha Reservoir

Shipyard	Location	Dock (wharf)	Annual production capacity
Dadong Shipyard	Zhangwanggang of Chongming Island; covering 782128.6 m^2; shoreline of 2300 meters; berth length 2290m.	4 Floating dock: DADONG (175,000 tons); HUADONG (150,000 tons); RUNDONG (50,000 tons); XINDONG (80,000 tons). 1dry dock of 30 million tons 5 deep water docks and 8 ship berths	More than 300 vessels above the 10,000 tonnages
Xinhua recycling shipyard	Xinhe town of Chongming Island	Scrapping Dock: 140 meters long; the design Berthing Capacity of 30,000 tons. Loading dock: 140 meters long; the design Berthing Capacity of 300 tons.	50,000 tons
Shanghai Shipyard	Xinhe town of Chongming; shoreline of 2.3km	2 Floating dock： XINXIANGSHENG(100,000 tons) HAIHUA(40,000 tons) Ship repairing wharf: 3 berths with total length of 760m; berth capacity of 100,000 tons Ship building wharf: 3 berths with total length 860m; berth capacity 100,000 tons.	Repairing: more than 100 vessels Building: more than 1,000,000 tons
Zhenhua Port Machinery yard	Majiagang of Changixng Island; shoreline 4500m	6 berths for 100,000 tons class crane loading; 1 berth for 70,000 tons class crane loading	Large quay cranes more than 300, and steel structure component more than 400,000 tons
Changxing Dangerous Goods Wharf	Changixng Island	2 Berths for 500 tons class cargo ship and one ferry berth of 60 meters	Uncertain amount of Paint and LPG
Changxing Shipbuilding Base	On Southeast of Changxing Island，total length 8000m	Line 1: 9 outfitting berths; 3 building material transport terminal and 4 large dock. Line 2: 3 outfitting berths; 2 material transport terminal and 4 large docks	Line 1: more than 4.5 million tons Line 2: for building special ships and ocean structures, under constructing, unknown
China-Shipping Shipyard	On the south of Changxing Island with total length of 3118m	3 Floating docks: PUTUO MOUNTAIN (80,000 tons); JIUHUA MOUNTAIN (200,000 tons); ERMEI MOUNTAIN (300,000 tons). 13 Berths for 50,000 tons class ships	More than 300 large vessels

Source: SHMSA, compiled by the author.

2.4 Vessel traffic around the drinking water source

Shanghai harbor is the highest areas of ship traffic density in China, much higher than that of other ports, particularly in the water area around Qingcaosha Reservoir. Liu Jun-yan (2013) carried out the statistical analysis of ship traffic in Yangtze estuary. The findings show that ships entering and exiting the South Channel had reached the number of 76,235 in 2007; it was about 208.9 ships per day. Ships coming in and out of the North Channel had reached 33,877 about 92.8 ships per day. From January to December of 2011, ships of 500 gross tons or 60 meters above passing through the South Channel around the Qingcaosha had reached number of 306, and the number of large vessels passed through the North Channel was about 130. Compared with 2007, both experienced a great increase. In 2012, about 25 to 30 chemical tankers carrying about 70,000 tons dangerous chemical goods passed through this region (Chang, 2014). The types of dangerous goods are more than 70 with toxic and strong pollution nature, such as xylene, phenol, styrene, aniline, carbon tetrachloride butyl acetate, etc.

In 2012, Chongming branch of SHMSA hold a ship flow test at the place of 404 floating light waters near the reservoir water intake gate. The results show that daily vessel flow was 90 ships (including 13 ocean-going ships, 77 river-going vessels, 3 dangerous goods carrying ships) (SHMSA, 2012a). In addition, Changxing Island of Shanghai is targeting to be the world's largest shipbuilding base. The concentrated shipyards in Chongming and Changxing Island will definitely make the increase the number of ships entering Chongming waters.

2.5 Summary

The environmental conditions around the drinking water source is rather complex. Apparently, high density of ship traffic in surrounding fairways and a large number of ships in shipyards and anchorages have brought a great risk of pollution. In particular, oil tankers and ships carrying dangerous goods passing through this water are threatening the safety of drinking water reservoirs.

Chapter III Risk Assessment of Pollutions from Ships on Water Source Protection Area

3.1 Main pollutants from ships

The ship-induced pollution to the marine environment means pollution caused by pollutants generated and discharged by ships during the process of navigation, berthing port, loading or unloading cargos and scrapping to the surrounding water or atmospheric environment (IMO, 2006). The main ship generated pollutants mainly include oil and oily substances, toxic and harmful substances, sewage, garbage and ballast water. After discharging into water body these pollutants will damage the marine biological resources, and destroy the water quality and finally affect human health other water-related economic activity.

Oil Substance

According to the different discharge source ship-induced oil pollution can be divided into:

a) Bilge water of Engine Room. If a vessel's oily or oil-mixed water does not undergo any treatment, it will exceed 10% of gross tonnage of the ship after one year, and the oil content of the bilge water in engine room water generally is 20-50g/L (2% - 5%) (Huang, 2013, p. 45). Taking a ship of 2500 gross tonnage as an example for calculation, the discharge of oily water will be roughly up to 5-10t in one year if no treatments held.
b) Ballast water in oil tanker. Ballast water refers to the bareboat sailing of oil tanker, in order to ensure the tanker seaworthiness, ships have to ballast the oil tanks and double bottom tanks with sea water to increase the ship's stability and draft. Oil tankers generally have at least 20% - 25% of the ballast water installed in cargo tanks of the ship. This part of the ballast water needs to be

discharged out of the ship after arrival at the loading port. The oil content of this kind ballast water is about 4-7g/L (Wang, 2009, p. 3).

c) Tank washings. When a tanker replaces the cargo oil or prepares to repair, the residual oil left on the bulkhead or in the bottom plate needs to be washed off. As a result, a large amount of washing water which mixes with oil will be generated during this operation. Also, before a tanker enters a dock for repair, it needs to clean all its cargo oil tanks to ensure no oil residuals are left on board. Usually, the remaining residual oil left on the ship is approximately 0.3% - 0.5% of the ship's carrying capacity after unloading of cargos (Wang, 2004). It means that a ship of 2,500 tons carrying capacity will make 5-12.5 tons residual oil.

d) Oil spills caused by ship accidents. They can be categorized into two types. Oil spills out from the breached fuel or cargo tank and pollutes waters due to the collision of ships, grounded, stranded, explosion or fire accidents of ships. Accidents occurrence is also due to poor quality of ship equipment, lack of maintenance, improper operation and lack of work checks (Chen, 2009).

Harmful substances

Ships transport many types of toxic and harmful substances which have different physical and chemical properties at present. Harmful substances usually have one or several attributes, which include corrosiveness, toxicity, flammability and explosiveness, self-reaction, heat sensitivity and so on. So during the shipping process, once the leakage accident happens, it will directly lead to the deterioration of environment, death of water organisms and destruction of ecological system, and finally influence the human health at the end.

Sewage

According MARPOL73/78, ship sewage covers any types of wastes discharged from the urinals and toilets on board, drainages from wash basin, bathtub and discharge holes of infirmary, the place for living animal and mixed sewage with above mentioned wasters (IMO, 2006). The untreated sewage contains various organic waste, pathogenic microorganism, bacteria, parasites, and eutrophicated substances. Once discharged into the water, it will lead to serious consequence of biochemical changes, and finally endanger marine life and environment.

Garbage

Garbage from ships includes plastics (mainly means synthetic rope, synthetic nets and plastic bags), floating dunnage, lining materials and packaging materials, paper products, rags, glass, metal, bottles, pottery and similar waste, grinded other wastes (including paper products, rag, glass, etc.), food waste without crush and grind, and other mixed wastes. If ship garbage is discharged into the water body, it will negatively change water constituents, like smell, color and quality, certainly make a resulting in changing the natural living conditions and affecting the human and marine life.

Ballast water

In order to control the draft, heel, trim, stability and hull stress, ships need to be ballasted with sea water. However, during this process, it will bring local aquatic organisms into the ballast tank. The aquatic organisms carried by vessels mainly include bacteria and other micro-organisms, small invertebrates and other species of eggs and larvae, and even some small fish. For these organisms carried by ships bring the risk of establishing new pollutions to a new marine environment, the discharge of ballast water poses a potential threat to local species or causes a wide range of ecological and environmental damage.

3.2 Types of risks of ship-induced pollution in water source protection zone

The wellhead protection zones are located in the mouth of the Yangtze River and close to the junction of the main channel of Shanghai Port. All ships entering ports inside of Yangtze River, Chongming Island, Changxing Island and Shanghai are threatening the surrounding waters, which make the situation of pollution particularly serious. The ship-induced pollution can be divided into types: the operational pollution and the accidental pollution, of which the former is generated from the daily operation of ships, and the latter is caused by ship’s accident during its voyage or loading and unloading operations (Chen, 2010). The accidental pollution may lead to very serious consequence due to a large amount pollutants discharged into waters in a short time. Once a traffic accident occurs at Shanghai Port or its surrounding waters, ship's fuel, cargo oil or liquid chemicals may spill into the water, endanger the to the marine l environment and drinking water source.

3.2.1 Operational pollution risk for drinking water source

The opeartional pollution risk means risk originated in daily ship’s activities. The pollution usually occurs in invisible or hidden way, such as small amount discharges of ballast water, sewage, chemical washing water and bilge water which cause normal contamination risks. For polluting the water source protection area, it is mainly embodied in two aspects: one is the unintended or intended discharge of ship’s daily pollutants by crews or shipyards nearby; the other is the residual pollutants of floating dock are discharged into water with the operation of submergence in shipyards or other pollutions made by ship-building, repairing and recycling yards, such as domestic garbage, industry garbage, paint, residual rust particles, and even dusts (Liu, 2010). These substances can float on the surface of the water forming a cover layer, or sink in the bottom of river to consume a large amount of oxygen in the waters, and it also causes great harm to the water quality and marine environment. For the Qingcaosha Reservoir, normal risk of contamination are usually from the surrounding anchorage, the passing ships in nearby waterways and ships or floating docks in shipyards around the water source protection area.

Currently, a total of six shipyards surround the Qingcaosha water source protection area. There are Dongdong Shipyard, Shanghai Shipyard and Xinhua Recycling Shipyard on south coastline of Chongming Island, as well as the Changxing Ship Building Base, China-shipping Shipyard and Zhenhua Port Machinery Yard on south coastline of Changxing Island. The statistics on dangerous operation with high pollution risks had been obtained in these shipyards from 2009 to 2011 (See **Table 3.1**).

Table 3.1: Number of ships' operations with high pollution risk in shipyards

Year	Liquid cargo barge transfer		Bunker transfer		Oil residual reception/clearance		Garbage reception		Ballast water discharge
	ships	tons	ships	tons	ships	tons	ships	m3	ships
2009	15	2660.2	926	193042.6	553	13425.65	146	989.41	429
2010	34	12100.3	1220	271447.52	739	16743.43	51	899.45	511
2011	30	11098.3	1410	272209.65	897	23115	123	985.31	474

Source: SHMSA, compiled by the author.

3.2.2 Accidental pollution risk for drinking water source

Since 2000, Shanghai Port has encountered several big water pollution accidents with bad consequences of threatening the safety of drinking water. For example, the collision accident of South Korea chemical tanker "GG CHEMIST" occurred in the waters of the Yangtze Estuary on April 8, 2005, which led to 67 tons of toluene and fuel leakage into the water. "ZHEHUANGJI 701" sank at the South Channel on June 27, 2006, and caused about 354 tons of 98% content sulfuric acid leakage (Weng, 2007). But it's even worse from 2009 to 2011; the pollution accidents caused by shipping activities had reached 10 around the water of Qingcaosha Reservoir. For instance, on June 12 of 2011, "KOTA WISATA", a ship was carrying the repair in the floating dock of "PUTUO MOUNTIAN" in China-Shipping Shipyard leaked about

1.1 tons of fuel oil into the river due to wrong operation by crews and workers of shipyard, and resulted in a large area of water contamination (SHMSA, 2011). The reservoirs were forced to shift the plan of taking water.

Compared with the operational pollution risk, the accidental risk are majorly brought from unpredictable incidents, such as collision, grounding, self-sank, or unintended discharge of pollutants caused by human errors. If pollution happens, the amount of leakage of pollutants may be larger than that from operational pollution in a short time. Furthermore, this kind pollution is usually hard to control and prevent, so if the information of accident is not clear, then there will be no effective measures to stop it. It is more likely to have a disastrous consequence. As a result, it is easy to cause greater social attention, therefore, it should be the key point that our research should focus on.

Based on the analysis of the **Table 3.2**, it is apparent that the risk source covers ships in shipyards and anchorages as well as the passing vessels in fairways. However, the highest risk is mainly from the traffic accidents and operational discharge of ships in shipyards, particularly, dangerous chemicals and oil tankers are the biggest threat to the safety of the drinking water source in the Yangtze Estuary.

Table 3.2: List of marine pollution accidents around Qingcaosha water source protection zone (2009-2011)

NO.	Time	Type of accident	Position of Accident	Consequense
1	February 14, 2009	"SUMMER CORAL" collided with "WANXUANCHEGNG013" and led to fuel oil leakage	0.3-0.4 nm downstream 68# floating light	About 100 liters of fuel oil leaked into water

NO.	Time	Type of accident	Position of Accident	Consequense
2	April 7, 2009	Oil spill accident of "STOLT MOUNTAIN", A Cayman Islands bulk chemical tanker	Waigaoqiao grain wharf	About 9 tons of soybean oil spilled from the cargo deck into the river, and shaped a 5nm stripe of oil film, damaged the water environment of Yangtze Estuary.
3	June 22, 2009	Collision accident of two pananma flag ships “SIAM BRIDGE” and“MARITIME ANITA”	South Channel A53 floating light	About 12,650 liters of lubricating oil and bilge water leaked into oil leaking into the South River Channel caused some pollution to water source protection zone under effect of wind and waves.
4	August 7, 2009	Collision accident of “ZHEQIANGJIANG00351”and “GLORIA”	Zhang Huabang 5# berth	About 9.7 tons heavy oil fell into water
5	September 6, 2009	Oil spill accident of “FENGXIANGLING”, happened during the refueling process	China-Shipping Shipyard12# berth	About 0.45 tons of 180 cst fuel oil spilled from air overflow pipe on the port side of ship.
6	March 28, 2010	Wrong loading operation of “DAQING 74”	Waigaoqiao oil refinery factory,0# berth	About 1.86 tons of crude oil overflow from the hole of slop tank on the starboard Waigaoqiao waters, wetlands, beaches were heavily polluted.
7	April 6, 2010	Collision accident of “RUBY”	No. 2 anchorage of Yangtze River Estuary	About14.0m ^{3}fuel oil fell into river

NO.	Time	Type of accident	Position of Accident	Consequense
8	February 23, 2011	Collision of “JINDE 3” and “XIRUI 503”	66# floating lights downstream the Wusong Warning Area	2 m ^{3}fuel oil fell into river
9	June 12, 2011	Wrong operation of“KOTA WISATA”during ship repairing	China-Shipping Shipyard	About 1.1 tons of fuel leaked into river, formed about 5000 meters long, 150-200 meters wide oil belt

Source: SHMSA, compiled by the author

3.3 Risk assessment of various ship-sourced pollution accidents

In this paper, a comprehensive evaluation method, the FSA (Formal Safety Assessment) is adopted to assess the risk of pollution accidents caused by various types of spills and leakage in the Yangtze Estuary of Shanghai Sector. The risk assessment is based on the statistics of ship pollution accidents in Shanghai waters from 2002 to 2012.

Table 3.3: Classification and comparison of ship-induced pollution accident in Shanghai water from 2002 to 2012

Types	Numbers of incidents	Percentage %	Total amount of leakage (ton)	Amount of leakage(per case)
liquid cargo operation	32	19.63%	6.775	0.2117
Bunker transfer	31	19.01%	0.7185	0.0231
Traffic accident	22	13.50%	1860.175	84.5534
Crew misoperation	17	10.43%	23.55	1.3853
Shipyard operation	16	9.81%	1053.528	65.8455

Intentional discharge	13	7.97%	14.225	1.0942
Equipment failure	11	6.75%	1.515	0.1377
Oil residual reception	7	4.29%	0.052	0.0074
Ballast water discharge	6	3.68%	0.346	0.0577
Barge transfer	4	2.45%	26.035	6.5088
painting work	2	1.23%	0.105	0.0525
Others	2	1.23%	0.105	0.0525

Source: SHMSA. The Annual Report of SHMSA (2002-2012)

3.3.1 Determination of risk probability of various pollution accidents

Base on the data in **Table 3.3**, the risk probability of pollution accident in the area can be divided into five ranks.

(1) Frequent Index 5: the percentage is over 25%, which is extremely frequent.

(2) Frequent Index 4: the percentage is 15-25%, which is frequent.

(3) Frequent Index 3: the percentage is 5-15%, which is reasonably probable.

(4) Frequent Index 2: the percentage is 1-5%, which is remote.

(5) Frequent Index 1: the percentage is 0-1%, which is extremely remote.

3.3.2 Determination of the severity level of risk consequence of various pollution accidents

In accordance with The Special Plan for Dealing with Ship-induced Pollution Accidents in Shanghai Port, the severity level of hazards is divided into four grades, including Minor (class-IV), Significant (class-III), Severe (class-II), Catastrophic (class-I)（SHMSA, 2010）.

(1) Minor (class-IV): the amount of leaked or spilled pollutants is less than 10

tons within a small area; the incident will not affect the sensitive area and be controlled by emergency response action. No derivative, secondary accident will happen.

(2) Significant (class-III): the amount of leaked or spilled pollutants is over 10 tons but less than 50 tons; Pollution accidents may have an impact on the sensitive areas, and cause mild damage or threat to public safety and social order in a certain range.

(3) Severe (class-II): the amount of leaked or spilled pollutants is over 50 tons but less than 100 tons (pollution accidents occurred in the water source protection zone and scenic areas are not limited by this number); pollution accidents may affect the sensitive areas and cause greater harm and threat to public safety and social order in a larger scale.

(4) Catastrophic (class-I): the amount of leaked or spilled pollutants is over 100 tons (pollution accidents occurred in the water source protection zone and scenic areas is not limited by this number); The scope and extent of hazards may exceed emergency response standard, and pose a severe threat to public safety and social order in a wide range. Besides, it may need unified command, public resource and power for emergency response disposal.

3.3.3 Determination of risk levels of various pollution accidents

On the basis of above standard of classification, comparing with the data in **Table 3.3**, the risk probability and severity level of hazards can be obtained (See **Table 3.4**).

Table 3.4: Determination of risk probability and severity level of various pollution accidents

Types	Percentage %	Frequent Index	Amount of leakage(per case)	Severity Index
liquid cargo	20.63%	**4**	0.2117	**IV**

loading/unloading				
Bunker fuel transfer	18.75%	**4**	0.0231	**IV**
Traffic accident	12.5%	**3**	84.5534	**II**
Crew misoperation	10.63%	**3**	1.3853	**IV**
Shipyard operation	9.38%	**3**	65.8455	**II**
Intentional discharge	8.75%	**3**	1.0942	**IV**
Equipment failure	7.5%	**3**	0.1377	**IV**
Oil residual reception	3.75%	**2**	0.0074	**IV**
Ballast water discharge	3.13%	**2**	0.0577	**IV**
Barge transfer	2.5%	**2**	6.5088	**IV**
painting work	1.25%	**2**	0.0525	**IV**
Others	1.25%	**2**	0.0525	**IV**

Risk Index is divided into three ranks including High Risk (Intolerable Risk), Critical Risk and Low Risk (Negligible Risk). According to the determined risk probability and severity level of hazards of various pollution accidents, the risk level of pollution accidents can be classified as shown in the **Table 3.5**.

Table 3.5: Risk levels of various ship-induced pollution accidents

Frequency / Severity	**1**	**2**	**3**	**4**	**5**
IV	Low	Low	Low	Critical (Bunker transfer/liquid cargo operation)	High
III	Low	Low	Critical	High	High
II	Low	Critical	High (Traffic accident/ Shipyard operation)	High	High
I	Critical	High	High	High	High

3.4 Summary

The risks of the ship-induced pollution to the reservoirs can be divided into two categories: the operational and the accidental pollution risks. Through the risk assessment of various pollution incidents, the main risks have been identified. Apparently, the traffic accidents, ships' pollution operation in shipyards, bunker transfer and loading or unloading operation of liquid cargo are on top of risk rank threatening the water source protection zones.

Chapter IV Current Status of Maritime Management on Preventing and Controlling the Ship-induced Pollution to Drinking Water Source

4.1 Relevant laws and regulations of maritime supervision

According to domestic legislation, China MSA as the competent authority of maritime safety management is authorized by Chinese government to take responsibilities of supervising ship-caused pollution to waters. And this has been clearly stated in many laws and regulations.

(1) Paragraph 2 of Article 8 of Law of People's Republic of China on the Prevention and Control of Water Pollution (2008): the prevention and control of water pollution from ships shall be supervised and inspected by China maritime administrations.

(2) Article 3 of Maritime Traffic Safety Law of the People's Republic of China (1983): The Port Supervision Bureau of the People's Republic of China (Former title of China MSA) is the competent authority for the implementation of unified supervision and administration of traffic safety in the coastal waters

(3) Paragraph 3 of Article 5 of Marine Environmental Protection Law of the People's Republic of China (1999): China Maritime Safety Administration is in charge of maritime affairs relating the supervision and management of marine pollution caused by non-warships and non-fishing boats, and is responsible for the pollution accident investigation and handling.

(4) Article 4 of Regulations for the Prevention and Control of Ship Pollution of Marine Environment (2009): China MSA shall, in accordance with this regulation, be responsible for the supervision and administration of the marine environment for the prevention and control of the ship and its related activities.

(5) Paragraph 5 of Article 6 of Regulations for the Safety Management of Dangerous Chemicals (2011): relevant competent transportation departments are responsible for safety management of road transportation, waterway transportation of dangerous chemicals, and have the right and obligation to issue licenses to water transport enterprises drivers, crew, loading unloading management personnel, escorts, declaration personnel, and container packing on-site inspectors.

(6) Paragraph 3 of Article 4 of Regulations on the Protection of Drinking Water Source of Shanghai City: The port and maritime administrative departments shall be responsible for the supervision and administration of the drinking water source of the port and ship pollution respectively.

4.2 Current measures of maritime supervision

At present, SHMSA has taken some dynamic and static measures to monitor the operational and the sudden pollution from ships. Dynamic measures means the using patrol cars, boats and aircrafts keep dynamic monitoring of ship's pollution incidents. Meanwhile, static methods usually include CCTV (Closed Circuit Television), AIS (Automatic Identification System) and VTS (Vessel Traffic Services) monitoring.

4.2.1 Prevention of operational pollution from ships

(1) Adopting new technology to strengthen the monitoring of high-risk vessels. In recent years, SHMSA has vigorously promoted the application of water traffic control system. Sufficient base stations of AIS covering whole water area have been built; all vessels entering the waters of Shanghai are required to install AIS terminals. Moreover, VTS provide high-risk ships with particular radar monitoring and navigation services. With the help of CCTV, AIS, VTS and other monitoring equipment, enhance supervision of ships carrying dangerous goods.

(2) With the implementation of the TSS (Traffic Separation Scheme) on Shanghai section of the Yangtze River, improve the safety of navigation.
(3) Enforcing the regulations of examination and approval strictly, focus on type and age of ships carrying dangerous goods. Strengthen surveillance of pollution prevention operations to increase the inspection of illegal discharge.
(4) Through strengthening the PSC (Port State Control) and FSC (Flag State Control) inspection to ensure seaworthiness of vessels, prevent the occurrence of ship accidents, and eliminate low standard ships.
(5) The applied ships entered o Shanghai port are required to sign the clean-up agreement with professional pollution clearance unit to ensure that the large ship and bulk liquid cargo ship will get assistance from social emergency power at the time of the accident happens, thereby reducing the risk of single ship pollution accident.

4.2.2 Prevention of accidental pollution from ships

SHMSA has established emergency response plans of handling the ship pollution accident. The organizational structure, responsibilities, procedures and later disposal are clarified. At the same time, the maritime sector ask the shipping companies, port, ship anti-pollution units within the jurisdiction to make emergency response plans to dovetail with its emergency response system.

In order to early detect and suppress the sudden pollution accidents, SHMSA has strengthened surveillance by airplanes, patrol ships and offshore monitoring stations to keep 24 hours' uninterrupted patrol.

Increase the reserves of anti-pollution materials. At present, it possesses 3 professional emergency ships, 6 supporting vessels, oil booms of 9,400 meters, 4 oil recycling pumps, 60 tons of oil dispersant and 40 tons of oil absorption felt in the Chongming Branch of SHMSA. Besides, in order to cope with the risk of chemical pollution in the waters near the Qingcaosha, Chongming MSA was equipped with anti pollution emergency equipment, including chemical adsorption agent (1.04 tons), 30 sets of chemical protective clothing (A, B, C class 10 sets respectively) and 10 sets of gas detector in 2012 (SHMSA, 2012b).

4.3 Difficulties in preventing and controlling pollution risks

Qingcaosha water source protection zone is located in a particular place where the water is sensitive and easy to suffer from the pollution of the ship. The reasons are as follow:

(1) The intake gate of Qingchasha wellhead is located only 4 nautical miles downstream the junction of Deep-water channel and Xinqiao channel. As it connects to channel water without effective barriers, the transport of oils and dangerous chemicals, traffic accident or operational errors all may pose threats to the water environment

(2) The unique geographical feature of Yangtze River Estuary determined that this area is affected by the ocean tide effect to a large extent. The river water keeps continuously reciprocating by the effect of periodical tide. Therefore, the diffused pollutants will be gathered at bank of river or coastal line of islands, which may greatly reduce the self-purification capability of the River and increase the difficulties in preventing and controlling pollution risks.

(3) There is an exclusive anchorage for ships carrying dangerous goods in Taicang port which is located at upstream of the Qingcaosha surrounding waters. Many bulk chemical ships are anchored in this region. Once the chemicals leak into the water, it is bound to affect the safety of Qingcaosha Reservoir.

The complex navigational and weather conditions make frequent traffic accidents near the water source protection zone. For instance, the narrow channel, large ship traffic flow and the seasonal strong wind or fog can easily lead to the dangerous ship grounding or collision.

The emergency disposal of chemicals is rather difficult, and there is no specialized rescue force to deal with chemical leakage in waters. Nevertheless, there are many kinds of dangerous chemicals and each has its own characteristic. Furthermore, the emergency treatment technology is complex, once the leakage contaminated waters, it is extremely hard to effectively control, collect, and remove the pollutants.

Large-scale chemical enterprises have been set along the banks of the Yangtze River by previous economic plan. As a result, the basic raw materials of chemical products are mainly transported through the Yangtze River. Undoubtedly, this brought enormous pressure of environmental pollution to Shanghai, a downstream city in Yangtze Estuary. Three-quarters of the total flow of the ship are transiting vessels. However, the current drinking water source protection regulations of Shanghai are not suitable for applying to dangerous chemicals carriers or oil tankers passing through the nearby waters of water source protection zones. Without mandatory regulations, maritime authorities cannot obtain important information beforehand, which includes the name of dangerous goods, characteristics, and emergency disposal methods. Therefore, in the event of chemicals leakage, maritime authority is not able to inform Qingcaosha water resources management department and other governmental entities in time to take emergency measures nor quickly organized emergency response.

4.4 Existing weaknesses of maritime supervision

4.4.1 Lack of communication mechanism

In fact, many governmental entities are involved in the management work of pollution prevention of water source, not only maritime authority, but also SOA (State Oceanic

Administration), Shanghai Water Authority, Shanghai Safety Supervision Bureau, reservoir managing company and some related parties. Nevertheless, communications with upstream maritime administrations is more important for preventing ships-induced pollution. Therefore, an information notification mechanism needs to be established.

Pollutants generated by sudden ship pollution accidents can arrive promptly at Qingcaosha Reservoir water intake under the influence of the river flow from upstream waters outside the jurisdiction of SHMSA. If the relevant governmental authorities can timely access to information related to the pollution to correctly take relevant prevention and control measures, the severity of consequence will be greatly reduced. However, for ship pollution accidents occurring outside its jurisdiction, it's still impossible to grasp related information and to take effective preventive measures timely till today. Therefore, the parties involved in protecting drinking water source of shanghai also should focus on communicating with upstream port terminals and maritime agencies. Currently, SHMSA is wishing to establish an information exchange mechanism, covering all MSAs concerned in the upper reaches of the Yangtze River, to avoid upstream toxic and hazardous substances polluting downstream waters.

4.4.2 Limitations of pollution clean-up capability and cost

Currently, Shanghai Port only possesses the emergency response capability of handling the oil spill, but has no professional rescue forces to deal with leakage or spill of dangerous chemicals. Through many years guidance of SHMSA, Shanghai port has set up an oil spill emergency response team which engaged in the social ship service parties as the principal force. These parties usually provide ships with services of receiving ship garbage, residual oil, oily water and other anti-pollution operations in the harbors. In recent years, they have gradually purchased clean-up materials, facilities and equipment to meet the requirements of SHMSA. These social organizations really have effects on control of oil spill accidents to some extent. Their equipment mainly include confining oil booms, suction linoleum, oil dispersant, oil recycling machines. All control methods are base on the principle of the insoluble character of oil in water.

However, the hazardous chemicals have diversity of properties, such as different water solubility, relative density, volatile and other physical properties. Chemicals leakage into water is more serious and complex than oil spill accidents, for the treatment is quite difficult. The existing oil spill emergency response team is not competent for chemicals leakage treatment neither in equipment preparation nor personnel training. Specialized emergency response power needs large investment, strong professional training and public support. Therefore, the establishment of emergency response team must rely on governmental guidance.

Compared with oily substances, chemicals are easily dissolved in water and other special properties, chemicals emergency disposal calls for higher standards of materials, equipment and techniques. Thus, the cost of rescue is more expensive, while the anti-pollution materials for chemical leakage are not commonly used. Therefore, the common business could not invest a big amount of money to store such rare pollution cleaning chemicals and equipment. In view of the fact, it is impossible to rely on the operation of the market to attract enterprises spontaneously to develop this type of professional companies. Moreover, the set-up of pollution emergency response team is mainly targeted to protect public interests, so it is reasonable to obtain the financial support from the governmental.

4.5 Summary

China MSA is the competent governmental agency taking responsibilities for preventing the pollution from ships. Nonetheless, protecting the drinking water source from pollution involves many governmental entities. Thus an effective coordination mechanism is necessary for dealing with pollution accidents. Meanwhile, there are some issues need to be solved by SHMSA, like team building of emergency response and reserve of anti-pollution materials and equipment. In addition, as the reservoir is so close to shipyards and channels, difficulties do exist in maritime supervisions.

Chapter V Countermeasures on Preventing and Controlling Pollution Risks

In accordance with the risk analysis in chapter III, the identified high risk sources are generally divided into two categories, one is the traffic accidents, and the other is the pollution operations of ships in shipyards. This chapter aims to find some effective countermeasures to reduce or control the risk of pollution for drinking water source.

5.1 Measures to reduce the pollution risks from ships in the shipyards

As the representative of the modern large-scale ship repairing enterprises, three big shipyards including Dadong shipyard, China-shipping Shipyard and Shanghai Shipyard have been built on Chongming Island and Changxing Island in the Yangtze River Estuary. With the development of Shanghai Port, the number of ships erntering into shipyards and docks has increased rapidly. Such sensitive waters are so close to shipyards that directly lead to a sharp increase of pollution risk in the drinking water resource. In face of the fact that more and more vessels are involved in pollution prevention operations and the safety pressure in protection of the surrounding sensitive waters is increasing, this paper intends to propose a closed-loop mode of anti-pollution supervision in shipyard, which includes three links, aiming to effectively control and reduce pollution from ships in shipyard. “Three links” means three phases including before, during and after the ship’s repair. The corresponding measures need to be taken for each link to create a closed-loop management system of anti-pollution.

5.1.1 Maritime supervision before ships’ repair

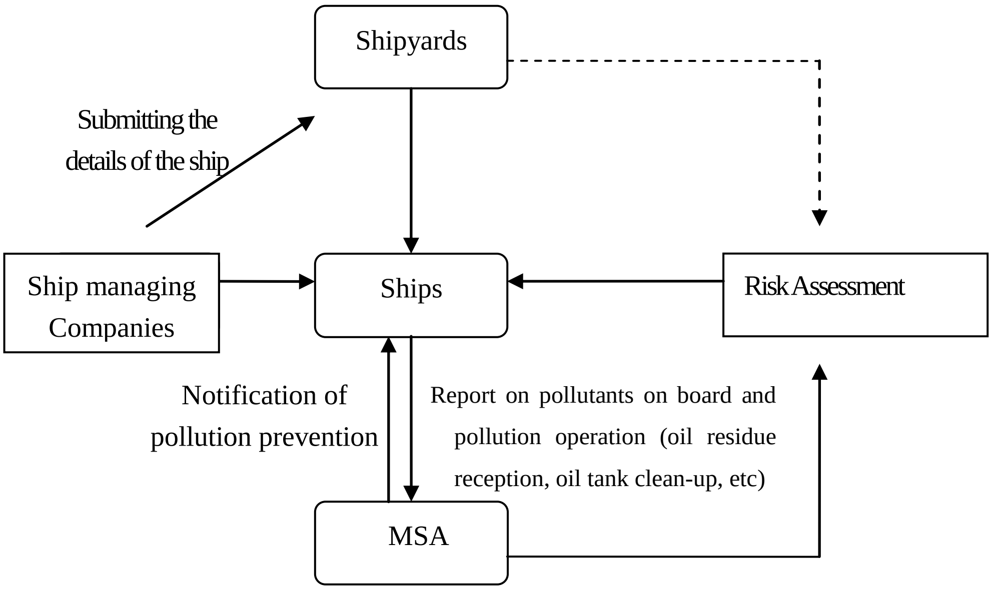

Figure 5.1: Maritime supervision before ships' repair

Before repairing, the ships should be ranked in the order of risk level. The MSA can carry out prior risk evaluation to determine the risk level of each vessel, and implement different measures of surveillance for specific ships.

(1) Red level: damaged ships caused by accidents ship, ships used to carrying dangerous goods, ships coming to repair for completing the transaction, ships in the blacklist, ships which need to repair fuel tank or fuel pipeline, ships reported with illegal discharge and other ships which need very strict supervision.

(2) Yellow level: vessels of flag of convenience, ships with record of pollution accident; ships need to carry out pollution operation of bunker or barge transfer and other ships which need for relatively strict supervision.

(3) Blue level: other ships which are not in the category of red and yellow levels.

If pollution risk of the ship is identified in the red level, after the ship berthing at shipyards, the related departments of MSA should assign qualified inspector to inform the relative personnel (including repairing manager, business representatives, engineering department and security department, representatives of shipowners) on board together, and join their ex-repairing meeting with crews, issue "Environmental Protection Notice" and inform the captain of the ship shall abide by the laws and regulations, pollution prevention reporting procedure and the operations prohibited. Moreover, inspectors will verify "Report of Pollutants for Repairing Ships" to avoid the risk of mis-operations of the ships or shipyards.

5.1.2 Maritime supervision during ships' repair

The repairing link is not only the most complicated section, but also most important task of maritime supervision, as it involves in numerous pollutants with high risks. The regulatory mode is shown in **Figure 5.2**.

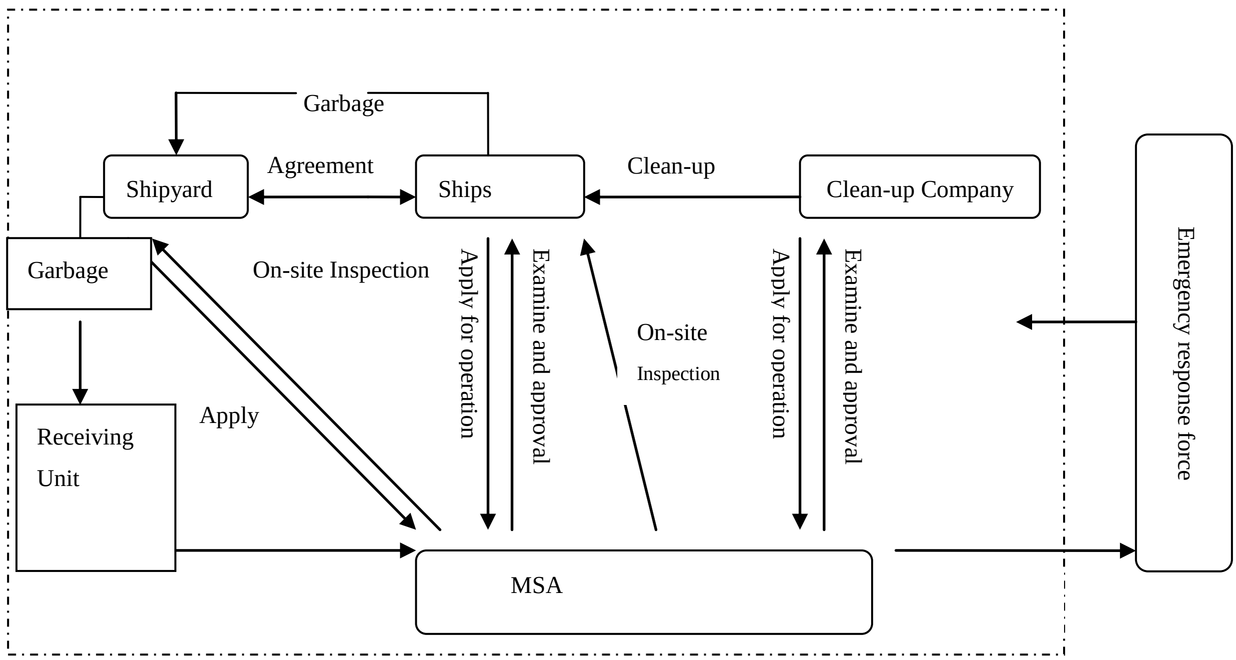

Figure 5.2: Maritime supervision during ships' repair

(1) To monitor all operations of high pollution risk during ships' repair which may cause pollution including disposal of marine pollutants, such as oil tank clean-up, oily water receiving, ship garbage receiving and sewage discharge; anti-pollution operations carried by shipyards, like dock sinking/lifting

operations, outboard chipping, hull scraping and painting operations; operations related to bunker transfer and relevant pollution operations related to certificates and records. Based on risk level of pollution from ships, the rate of on-site inspection will be confirmed, and then MSA will assign qualified personnel to inspect it. Therefore, this effective monitoring method is used to achieve the goal of reducing the risk of contamination and eliminating the operational pollution accident.

(2) To inspect emergency preparedness of anti-pollution. The inspection should cover all emergency response force, the preparedness of anti-pollution equipment, emergency personnel training and duty, update of emergency response plan, etc.

5.1.3 Maritime supervision after ships' repair

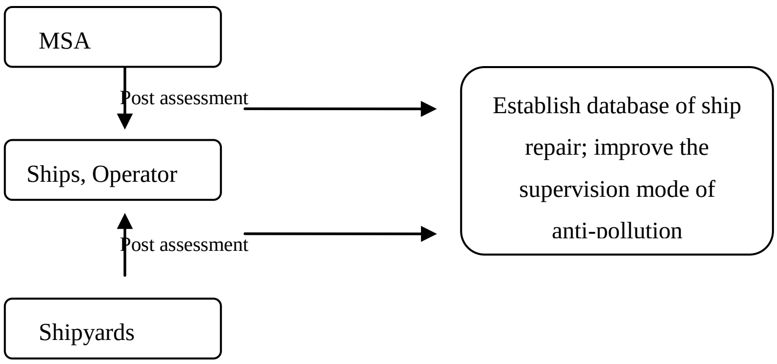

Figure 5.3: Maritime supervision after ships' repair

The post-assessment should be held when the ship's repair is completed. The effect of supervision needs to be measured by performance from risk pre-assessment before ships' repair, on-site inspection during ships' repair, pollutant treatment, anti-pollution measures of ships and shipyards. The feedbacks will be collected and distributed to all related parties, and then a database of repaired ship can be set up for the purpose of constantly improving supervision mode.

5.2 Measures to reduce the pollution risks from ships' accidents

According the Regulations on the Protection of Drinking Water Source of Shanghai city (2009), there are two ranks of protection zones. Class-1 protecting area covers the water inside the reservoir and waters 200m outside the boundary dam of reservoirs and 500m outside the intake water gate; the Class-2 protection zone involves all waters 1,700m outside the boundary dam of reservoir. Nevertheless, the Class-2 protection zone of Qingcaosha Reservoir goes across two fairways and the width of 1,700 meters is not enough to deal with sudden vessel pollution accident. This paper proposes adapting the Regulations on the Protection of Drinking Water Source in Shanghai by establishing the ecological sensitive water areas outside the Class-2 water source protection zones. Yang-Hong (2015) developed his research on ecological environmental risk zoning of oil spills in Shanghai water area, and made a conclusion that the surrounding waters of Qingcaosha Reservoir have the biggest sensitivity coefficient of ecological sensitive area, and drew the ecological risk zoning map of oil spill. Based on his study, **Region II** in the **Figure 5.4** has the highest risk of pollution. Therefore, this paper considers **Region II** should be recommended as the ecological sensitive area for protecting reservoirs. Meanwhile, within the ecological sensitive area of water source, some special rules need to be developed.

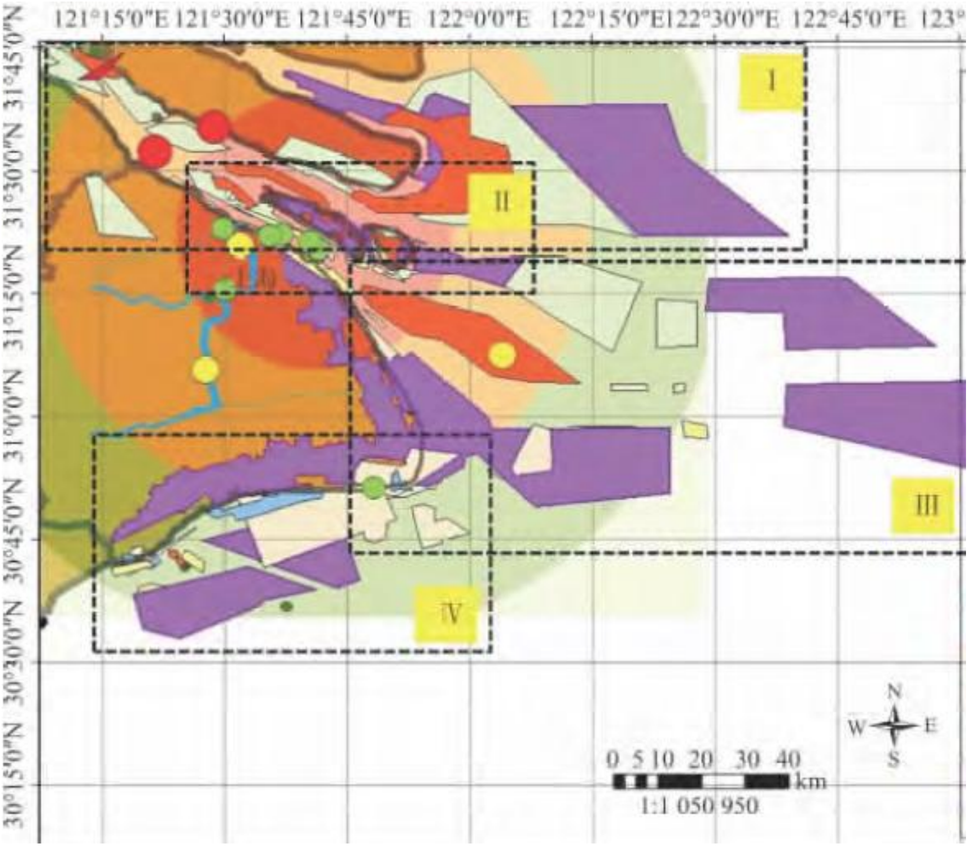

Figure 5.4: Ecological Risk Zoning Map of Oil Spills on Shanghai Water Area

Source: Yang, H. (2015). Resources and Environment in the Yangtze Basin

(1) Limit the ship's speed inside the ecological sensitive area of water source. For ships navigating in fairways which are inside the ecological sensitive area of water source, speed shall not exceed 12 knots, and vessel overtaking is prohibited.

(2) Introduce ship escorting and piloting system for ships sailing inside the ecological sensitive area of water source. In fact, Yangtze River of shanghai sector had implemented the mandatory pilotage regulation for foreign vessels in accordance the Regulations of Ship Traffic Management in Yangtze River Estuary of Shanghai Sector (2005). However, there are no rules for domestic ships carrying dangerous goods. So it is recommended to increase requirements of mandatory escort and pilotage for vessels carrying 500 tons and above category X substances, substances with high viscosity and solidification of category Y or toxic chemicals in bulk liquid. These ships

shall apply for convoy by patrolling boats from MSA or tugs on their request, when they are sailing in the ecological sensitive area. Certainly, mandatory pilotage is also needed.

(3) Providing suggests for particular ships with high risks of pollution to reach an agreement of pollution clearance with pollution emergency response force. Some old ships with bad PSC or FSC inspection records, especially oil and chemical tankers are required to sign the agreement of pollutants clean-up with qualified company. In case the accident happens, there is an agreement to ensure emergency response operation can be carried out in time to effectively minimize the pollution damage.

5.3 Establishing the coordination mechanism of pollution monitoring and information communication

At present, the management departments of reservoirs are not clear on the risk sources of pollution outside reservoirs, and have not installed pollution monitoring system on the water around the water source protection zones. Also ship pollution information tracking and risk early warning mechanisms have not been established. Therefore, a coordinated mechanism of water pollution monitoring and information communication needs to be established as soon as possible to satisfy all parties which have obligations to protect the reservoirs from pollution. The CCTV monitoring system and other advanced remote sensing devices can be installed on water areas of high pollution risk. The “priority watch list” should cover the boundary of water source protection zones, shipyards front waters, anchorage waters and key fairways; so that at emergency response force can take actions when pollution accidents occurred. In addition, threat warning level will be given base on prediction model and field investigation. All the information and monitoring data concerning marine pollution will be collected by Shanghai Maritime Search and Rescue Center for a comprehensive analysis.

At the same time, for the emergency response of pollution accident involves many government entities including MSA, Environmental Protection Agency, Water Affair Authority and Oceanic Administration. These governmental departments should enhance communication and cooperation, share the real-time data of monitoring of water quality and related information, in order to facilitate the analysis of ship-induced pollution, and organize emergency handling forces for effective cleaning and control of pollution in the first time. The coordination mechanism is able to integrate all available resources of various government entities to form one power and avoid the overlap or miss of work responsibilities.

5.4 Summary

These countermeasures are aimed at preventing the normal pollution from ship's operations in shipyards, and reducing the accidental risks caused by ship traffic accidents. In order to improve the maritime supervision on ships in shipyard, a closed-loop management mode including three links has been proposed. For the purpose of reducing the pollution incidents caused by water traffic accidents in nearby waterways, establishing an ecological sensitive area of drinking water source which has special requirements of navigation for vessels sailing inside seems to be a good approach to decrease the traffic accidents and minimize the risk probability. In addition, it is necessary to establish a coordination mechanism of pollution monitoring and information communication among various governmental entities for improving the emergency response capability.

Chapter VI Conclusions

In view of the importance and urgency of protecting the drinking water source in the Yangtze River Estuary, this paper has proposed three corresponding countermeasures through studying the surrounding water environment of reservoirs, risk assessment of ship-sourced pollution nearby and analysis of current management status and existing problems in maritime supervision of drinking water source from the perspective of maritime administration. In order to make the suggestions more feasible, all governmental entities involved in the water source protection should strengthen the information communication and work together to establish a coordination mechanism.

In short, the environment of water around the water source protection zone is rather complex. It is apparent that the special geographic locations, particular water condition, high density of ship traffic and numbers of repairing shipyards have posed great pollution risks to drinking water source. However, the risk of ship-induced pollution to reservoirs can be divided into two types: the operational risk and the accidental risk of pollution. Subsequently, the paper has identified the items of pollution with high risks by means of Formal Safety Assessment, based on many years' statistics of ship pollution accidents in Shanghai waters. In addition, based on the author's work experience, the difficulties of pollution prevention for reservoirs have been analyzed, and the weaknesses of maritime supervision have been pointed out.

Moreover, this paper has presented a closed-loop model of maritime supervision to solve the issue of ship-sourced pollution in shipyards. On the other hand, for the purpose of tackling pollution caused by ship accidents, it is proposed to modify the Regulation on Drinking Water Source Protection of Shanghai City on enlarging the drinking water source protection area. Therefore, the opinion of establishing the ecological sensitive area of wellhead has been put forward. Vessels sailing inside the ecological sensitive area of wellhead shall obey some special rules of navigation, like restriction on ships' speed, mandatory pilotage and discharge.

It is better to prevent ship-induced pollution from happening rather than try to deal with the problems after it has happened. The maritime agency must be able to catch the information of high risk ships through the preliminary risk evaluation as soon as possible and enhance the supervision on these vessels. Meanwhile, the supervision of ship's operational pollution and on-site inspection of pollution operation need to be improved as well. Furthermore, SHMSA should pay attention to scientific research on developing the emergency response plan on anti-pollution, promote team construction of pollution emergency treatment, in particular, to promote its ability of pollution prevention in handling dangerous chemicals leakage or spill accidents on waters.

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