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Maritime environmental influence of large-scale tanker on the water area of Tianjin port

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MARITIME ENVIRONMENTAL INFLUENCE OF LARGE-SCALE TANKER ON THE WATER AREA OF TIANJIN PORT

By

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Declaration

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

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

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Abstract

Title of Research Paper: **Maritime Environmental Influence of Large-Scale Tanker on the Water Area Of Tianjin Port**

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The sustainable development of Tianjin port, the largest comprehensive foreign-trade port in North China and one of the central ports of the country, has been broadly concerned. During the time of the 11th Five-Year Plan, along with the development of Tianjin Binhai Area, the cargo handling capacity experienced a rapid growth, and so did the ship number and shipping density. At the same time, tonnage of a single ship also greatly increased.

The constant increase of tonnage and the scale of oil tanker will significantly increase the risks of oil spill in our country. In order to have a deeper study about the influence of large-scale oil tanker on the maritime environment, this paper selects the water area of Tianjin Port as the research object, by using the method of Environmental Risk Prediction, it analyzes the traffic volume, accident rate, and possible consequences in the last few years to make a reasonable prediction of oil spill risk and draw to a conclusion.

From the calculation in the paper we can see that upsizing the scale of oil tanker is beneficial to reduce the risk of oil spill in the water area of Tianjin Port, which has a positive effect on the maritime environment. But at the same time, since the scale of oil tanker increases, the amount of spilled oil goes far larger than before in a single accident, which tends to cause a devastating result to the environment in nearby water area and coast line. Therefore, when advocating the development of large-scale oil tanker, we should pay more attention to the navigating safety of large tankers, as well as the preparation and countermeasures of accidents.

KEYWORDS: Large-scale, Oil tanker, Environmental, Risk evaluation

Table of contents

List of tables

List of figures

List of abbreviations

CNOOC	China National Offshore Oil Corp.
DNA	Deoxyribonucleic Acid
DWT	Dead weight Tonnage
GOP	Gross Oceanic Product
RMB	Renminbi
VLCC	Very Large Crude Carrier
VTS	Vessel Traffic Services

1. Introduction

1.1 Background

With the rapid development of Tianjin Port and the construction of northern international shipping center, the handling capacity of bulk oil in Tianjin has experienced a fast growth. In 2007, the handling capacity was 29.15 million tons, which was 5.6 times than that in 2000. Especially that as a supporting project of Millions of Tons of Ethylene Project of Tianjin Petrochemicals, the first crude oil terminal of 300,000 tons was put into operation in September, 2008 in Tianjin Port, and the second one was constructed at the end of 2009. In recent years, the handling capacity of bulk oil in Tianjin Port has increased year by year and reached 50 million tons in 2010 (Hong, 2008). At the same time, the traffic volume of large-scale oil tankers has also achieved substantial growth.

In 2007, the number of commercial transportation vessels entering and leaving Tianjin Port reached 91,362, and the traffic density also increased sharply. Meanwhile, as reconstruction work was launched in the port, a large number of workboats and sand carriers rushed into the port, which seriously influenced the navigating safety. Besides, some areas had single shipping lanes with complicated hydro meteorology situation. A combination of these factors could easily lead to collisions or stranding of ships which would cause particularly serious accidents and pollution. If the pollution is from the collision of large-scale tankers, the consequences would be disastrous. For instance, in 2002, the tanker of “Tasman” which carried 80,000 tons of crude oil had a collision and oil leaking of more than 200 tons of crude oil, which caused a terrible consequence to the water area of

Tianjin (Shen, 2011).

The tendency of upsizing oil tanker is inevitable. Large-scale tanker brings high unit efficiency, but its environmental impact still needs a further research.

1.2 Significance of the Study

Nowadays people use advanced large-scale oil tanker simulators to achieve simulation of navigation both at home and abroad. The purpose of that is to use the theoretical knowledge and navigating experience of navigable evaluation to study the sailing situation of large-scale oil tanker and at the same time to reduce the rate of oil spill incidents through the control of traffic status.

Tianjin Port is one of the greatest artificial harbors around the world. It is also one of the most important ports in China. Tianjin Port is located in the estuary of Haihe, facing the Bohai Harbor. Rich oil resources and dense oil platforms in Bohai Harbor make the traffic volume in Tianjin Port not only mass but various, which will eventually lead to a dangerous traffic situation within the harbor (Liu, 2003). The study on the large-scale oil tanker in Tianjin Harbor aims to reveal the maritime environmental influence of large tanker on this water area, and furthermore put forward the corresponding countermeasures.

1.3 Method of the Study

Large-scale tankers generally refer to the oil tankers with a total tonnage of more than 100,000 tons. They have some distinguishing features like a large displacement, a strong inertance, a poor performance on stopping ability and control of the rudder. The research methods in this paper mainly include: collecting the historical data of oil spilling incidents in Tianjin Harbor, analyzing the connection between the tonnage of a ship and the pollution situation with the method of environmental evaluation, and using mathematical equations to draw a reasonable prediction of pollution situation.

1.4 Layout of the Study

The first part of this paper is the introduction part, which mainly introduces the general background, the significance, the method and the purpose of the research.

The second part takes the large-scale oil tanker as the object of study and gives a detailed description about the recent status of the large tanker, the construction features of the ship and the working patterns respectively. Then, in the third part, we take the water area of Tianjin Harbor as the object of the study to analyze the maritime environment, the natural self cleaning capacity, the human ability of pollution prevention and the construction situation of large crude oil terminal in Tianjin Port, and furthermore to reach a pollution hazardous evaluation.

The fourth part in this paper cites some historical data to have a statistical analysis on oil spilling incidents in this harbor, and gives a further pollution prediction in the next few years according to the historical data.

The fifth part raises some corresponding countermeasures of oil spilling incidents and the last part of the paper is the conclusion and prospect.

2. A Brief Introduction to Large-scale Tanker

2.1 The Concept and Recent Status of Large-scale Tanker

Large-scale tankers generally refer to oil tankers with more than 100,000 tons dead weight. They can be further divided into supertanker, which has a gross tonnage of 200,000 tons to 400,000 tons, and VLCC, which has a tonnage of more than 400,000 tons. The sizes and drafts of large-scale tankers are shown in the Table 1.

Table 1- Sizes and Drafts of Large-Scale Tankers

DWT（t）	Ship Sizes（m）			
	Length (L)	Breadth(B)	Depth(D)	Draft(D)
250,000 （185,001-275,000）	333	60.0	29.7	19.9
300,000 （275,001-375,000）	334	60.0	31.2	22.5
450,000	380	68.0	34.0	24.5

Source: Specifications of General Layout of Harbors (JTJ211-99) Appendix, March 2008 Revision

2.2 Constructional Features of Oil Tankers

The Bohai Bay is the only continental sea in China. The navigational condition is very complicated here. Bad sea conditions like large waves and poor visibility appear at a high frequency, and the current VTS system cannot achieve an all-around coverage of service on a support of traffic information (Luo, 2009). In addition, many features of large vessels are different from ordinary ships, thus making the navigation safety issues of large vessels in these waters increasingly prominent. This chapter is going to further introduce the distinguishing features of large tanker based on the particularity of navigation environment of Bohai Bay, discussing the sailing characteristics of large ships in Bohai Sea, and make it a basis for further research.

2.2.1 Example Analysis of Distinguishing Features of Large Oil Tanker

Since different types of large tankers have broadly similar sizes and operational characteristics, this paper is going to take the Greek tanker "Astor", which has a tonnage of 300,000 tons, as an example to discuss some features (Wang & Xu, 2007).

1) Ship Parameters of "Astor"

Displacement: 321260t, DWT: 279400t, Length L_{OA}: 332.0m, L_{BP}: 320.0m, Breadth: 58.0m, Depth: 33.2m, highest point to the ship keel height: 67.0m, laden draft: 20.8m, block coefficient: 0.80, longitudinal metacentric height: 342.4m, transverse metacentric height: 6.41m, the point of gravity to the center of the boat: 0.4lm, the point of gravity to base line: 17.63m.

A diesel engine of 23493kw, with normal and emergent remote control system, the minimum rotate speed: 22RPM, the sailing speed at minimum rotate speed: 4.4kn.

A fixed pitch propeller, diameter: 9.70m, the highest pitch from water surface: 15.42m, direction of rotation: clockwise, slip ratio: 0.67.

An ordinary balanced rudder, effective area/total area (RAR): 100%, total area: 109.4m^2, maximum rudder angle: 35^o.

Comparisons between the main engine of the ship and the sailing speeds, as well as the time consumption of telegraph change-over are shown in the table 2 and 3.

Table 2- Caparison between Rotation Speed of Main Engine and Sailing Speed

Telegraph Orders	Rotation Speed of propeller（RPM）		Sailing Speed（kn）		Power （A）	Slip Ratio
	A	B	A	B		
Advance 4	78	77	15.7	14.1	22345	0.67
Advance 3	72	71	14.5	13.2	17579	0.67
Advance 2	64	63	12.8	11.9	12308	0.67
Advance 1	45	44	9.0	8.4	4282	0.67
Dead Slow Ahead	27	27	5.5	5.1	932	0.67
Dead Slow Astern	-28	-28	-1.6	-1.4	1987	0.67
Back 1	-38	-38	-2.4	-2.1	5066	0.67
Back 2	-47	-47	-3.0	-2.7	9647	0.67
Back 3	-55	-54	-3.6	-3.3	15394	0.67
（A） deepwater，depth of water is 1000M （B） shallow water，draft=1.2						

Table 3- Time Consumption of Telegraph Switch

	Time Consumption（min-sec）	
Telegraph Switch Way	Normal	Emergent

Advance 4—Back 3	9-18	4-28
Advance 3—Back 3	4-32	2-49
Advance 2—Back 3	2-12	0-37
Advance 1—Back 3	0-24	0-24
Dead Slow Ahead—Back 3	0-20	0-20
Advance 4—Stop Engine	16-42	13-24
Advance 3—Stop Engine	11-56	11-56
Advance 2—Stop Engine	9-35	9-35
Advance 1—Stop Engine	1-11	1-11
Dead Slow Ahead—Stop Engine	0-04	0-04

2) Circling Performance

Table 4- Rotor angle (advance four, rudder angle 10°)

Rotor Angle	Time （min-sec）	Sailing Speed （kn）	Speed of Rotor Angle （degree/min）	Longitudinal Distance	Transverse Distance
10	1-03	15.5	17.7	2.71	0.08
20	1-32	15.0	23.3	3.92	0.26
30	1-56	14.4	25.4	4.88	0.55
40	2-19	13.8	25.6	5.70	0.92
50	2-43	13.1	24.7	6.44	1.42
60	3-08	12.4	23.7	7.08	2.03
70	3-34	11.8	22.8	7.59	2.71
80	4-01	11.2	21.9	7.98	3.47
90	4-29	10.7	21.1	8.24	4.28
100	4-58	10.2	20.4	8.34	5.12

110	5-28	9.8	19.8	8.30	5.95
120	5-58	9.5	19.2	8.12	6.75
130	6-30	9.1	18.6	7.81	7.51
140	7-03	8.8	7.37	8.19	18.2
150	7-36	8.6	17.8	6.82	8.78
160	8-10	8.3	17.4	6.19	9.27
170	8-45	8.1	17.0	5.49	9.63
180	9-21	7.9	16.7	4.74	9.87
270	15-03	6.9	15.1	-0.55	6.55
360	21-08	605	14.6	2.68	1.42

Table 5- Rotor angle (advance four, rudder angle 20^o)

Rotor Angle	Time（min-sec）	Sailing Speed（kn）	Speed of Rotor Angle（degree/min）	Longitudinal Distance	Transverse Distance
10	0-45	15.4	24.8	1.95	0.04
20	1-06	14.9	30.5	2.82	0.16
30	1-25	14.1	32.0	3.56	0.35
40	1-44	13.3	31.0	4.23	0.63
50	2-04	12.5	29.6	4.83	1.01
60	2-25	11.7	28.3	5.35	1.46
70	2-47	11.0	27.0	5.79	2.00
80	3-09	10.3	25.9	6.11	2.58
90	3-33	9.7	24.8	6.33	3.20
100	3-58	9.1	23.8	6.44	3.83
110	4-23	8.6	22.9	6.44	4.46

120	4-50	8.2	22.0	6.34	5.08
130	5-18	7.8	21.3	6.13	5.65
140	5-47	7.4	20.5	5.83	6.18
150	6-16	7.1	19.9	5.45	6.64
160	6-47	6.8	19.3	5.01	7.02
170	7-18	6.6	18.8	4.51	7.32
180	7-51	6.3	18.4	3.96	7.53
270	13-06	5.1	16.3	0.05	5.45
360	18-45	4.8	15.7	2.00	1.76

Table 6- Rotor angle (advance four, rudder angle 35^o)

Rotor Angle	Time （min-sec）	Sailing Speed （kn）	Speed of Rotor Angle （degree/min）	Longitudinal Distance	Transverse Distance
10	0-37	15.3	34.1	1.58	0.03
20	0-52	14.6	40.7	2.22	0.10
30	1-07	13.8	40.1	2.79	0.24
40	1-23	12.8	37.6	3.32	0.44
50	1-39	11.8	34.9	3.81	0.72
60	1-57	10.9	32.5	4.24	1.06
70	2-16	10.0	30.5	4.61	1.47
80	2-36	9.2	28.6	4.91	1.93
90	2-58	8.5	27.0	5.11	2.41
100	3-21	7.9	25.5	5.23	2.92
110	3-45	7.3	24.2	5.26	3.42
120	4-10	6.8	23.1	5.21	3.92

130	4-37	6.3	22.1	5.08	4.38
140	5-05	5.9	21.3	4.88	4.81
150	5-33	5.6	20.6	4.62	5.18
160	6-03	5.3	20.0	4.30	5.49
170	6-33	5.0	19.5	3.95	5.74
180	7-04	4.8	19.0	3.57	5.93
270	12-09	3.7	16.8	0.66	4.75
360	17-38	3.3	16.2	1.69	2.10

2.2.2 Review of Constructional Features of Large Tankers

Basing on the data, the sizes of large-scale oil tankers are tremendous huge, the area of deck can be as extent as 2-3 standard soccer stadiums, and its depth can also be as abyss as 10 floors' building. In respect of its capacity, the design of its appearance is usually "obese", namely, its size is apparently super large. Considering the facts above, large-scale oil tanker has its exclusive traits than normal cargo carriers; length-width ratio (Lbp/B) is lower, close or slightly higher than 6.0-6.7. Coefficient ratio is larger, usually more than 0.8, and its coefficient ratio is still higher than 0.75. The proportion of width and draft is generally large, usually larger than 2.5, and it can turn around smooth by the boost of obese design of bodies. Besides, the proportion of effective area is smaller, usually 1/65-1/750 (Shi & Chen, 2011). Additionally, Major engines' power gets larger when the size grows bigger, and also dead weight is fairly large, major engines' power per ton will be very small. Thereby, backing speed can only be 30% of the forwarding speed, usually under 6kn.

As regards the large ratio of coefficient, small proportion of length and width, small ratio of width and draft, its operability index T and K are pretty large. Then ships display its dysfunction in following, directing and agility in turning around.

Small rudder angle is weak, within 5° almost no effect on the response of movement. Applied rudder, once the bow began to deflect it up, it is difficult to stabilize on new direction. Large-scale oil tanker loses its steerage earlier relatively, which is about 3Kn. Because of its large momentum, it is not easy to start and stop. A full loaded large-scale oil tanker will take more than 1h and 20-time ship length to stop from full-speed to 3Kn (Hu, 2006). Affected by cross wind, its drift speeds can reach up to 4% to 5% of the wind speed. Experience has shown that when the wind abeam the ship, fully loaded ship when the wind speed is 6 times the speed, ballast ship when the wind speed is 4 times the speed, it is extremely difficult to keep the direction. When the tanker goes from deep water into shallow waters, the ship resistance increases and speed reduction occurs; low pressure area of mid-ship will extend to the stern, the hull sinking a little bit, accompanied with changing trims, the propeller blade thrust significantly different between the upper and lower, and hull vibration phenomena more obvious (Xi, 2009).

2.3 Operating Characteristics of Oil Tanker

It is no more than 20 kilometers from Tianjin port to the west area of large tankers'route. The waters with their jurisdiction has a lot of drilling platforms, which means a huge demand for tankers, and also increases the burden and risks on route. At the same time, the characteristics of the operation of tanker also contribute to the potential risk of oil spilling.

2.3.1 Entering and Leaving Port for Large-scale Tanker

When large tankers leave the port, the shallow water level in loading and unloading dock will cause grounding or shallow water effect, so that the normal navigation of oil tankers is subject to certain restrictions, and this will cause a certain degree impact on the loading and unloading operations (Zhang, 2008).

Moreover, based on the fact that there are various directions and angles on the different routes, a risk surely exists when turning the direction, which is not conducive to the loading and unloading operations. Besides, the condition of water itself can also affect the normal navigation of oil tanker. For instance, when a tanker comes across an ebb tide, the operational difficulty will increase, which is not only bad for loading and unloading but also brings risks. From the above analysis, the navigation of large-scale oil tanker must be affected by a lot of factors, which will increase the operation difficulty, decrease the loading and unloading efficiency, and bring risks.

2.3.2 Berthing and Un-berthing for Large-scale Tanker

Under normal condition, large-scale oil tanker should discharge the oil after finishing berthing, and after the discharging, the next process is un-berthing, so we can see that berthing and un-berthing play an important and prerequire role for safe discharging (Han, 2009).

It is embodied in the following two aspects: one is when the water flows faster, it will cause tankers not to be piloted effectively, so that smooth berthing and un-berthing will not be ensured; on the other hand, the tanker also experiences an uneven force of wind resistance, thus affecting the smooth loading and unloading operations.

As a tanker's body is very large, it is very difficult to take a U-turn way to re-berth, and these various loading and unloading operations will lead to an increased risk.

2.3.3 Risk in Discharging

In discharging, the most important process is the oil discharging. Generally, the risks in the process of oil discharging can be concluded as follow: Firstly, when unloading the ship, the improper operation may cause oil leakage into the pump or other warehouses, or make the oil flow into the waters, causing a fire or explosion. Secondly, the operation order of discharging is improper or excessive discharging speed may affect the stability, thus the structure of the ship. Third, in the discharging process, the tanker is always in a floating state, so in the case of an emergency, it is difficult to evacuate quickly (Tian, 2006). Fourth, crude oil washing is an important element of the whole prosses, the general approach adopted by the crude oil washing machines are ejected, and with the high solubility of crude oil that produced during ejected out of the vortex achieve cabin sludge dilution and dissolution, as need for crude oil washing high-pressure injection, thus there is a higher safety risk. Fifth, human factor is another very important issue. Since there are a lot of complicated operation in discharging, mistakes and wrong operation exist and are sometimes ignored.

3. Bearing Capacity of Tianjin Port to Large Tankers

3.1 Work Zone, Construction of the Terminal and Navigational Situation in Tianjin Port

According to the statistics from Tianjin Maritime Safety Administration, China National Offshore Oil (Tianjin) Corporation, Shengli Oilfield, and Roc oil Company have more than 1000 oil platforms in total in Bohai Sea, more than 400 of which are allocated within the isobaths below 10m. These platforms are mainly gathered in Laizhou Bay and the northern Yellow River Delta in Western Bohai Bay, the remaining are distributed in Liaodong Bay and western Bohai Bay. What impacts navigation safety obviously is the platforms outside the 10m isobaths. The offshore oil fields are shown in the Figure 1.

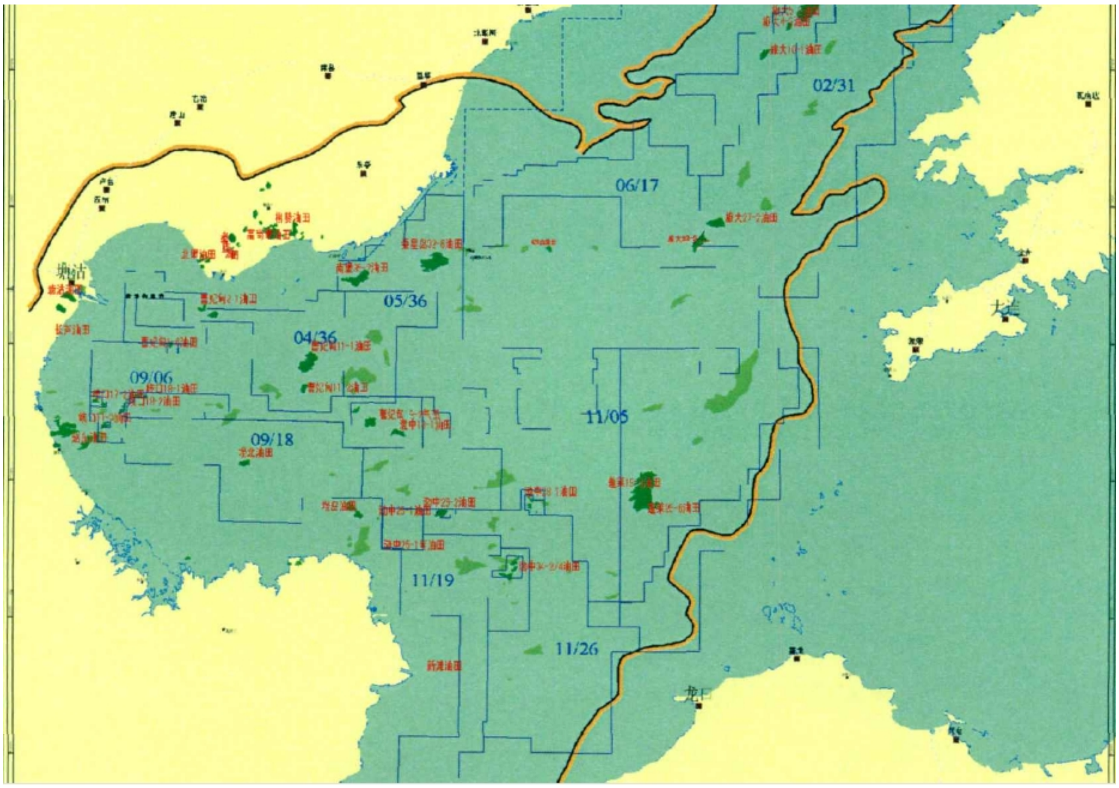

Figure 1- Offshore Oil Fields in Bohai Bay

Geographically, Bohai Bay concatenates Liaoning, Beijing, Tianjin and Shandong coastal economic zones. With the development of Tianjin Binhai New Area, the construction of Caofeidian Industrial Center and the discovery of the largest offshore oil field Nanbao, the economic development around Bohai Bay began to grow rapidly in recent years. The construction of 300,000-ton VLCC terminal has also quickened the pace. On October 29, 2008, the 300,000-ton crude oil terminal achieved its first oil tanker berthing in Tianjin Port (Chai & Chen, 2008). Bohai Bay oil terminal port showed an unprecedented gesture. The constructional situations of VLCC terminals are reflected in Figure 2.

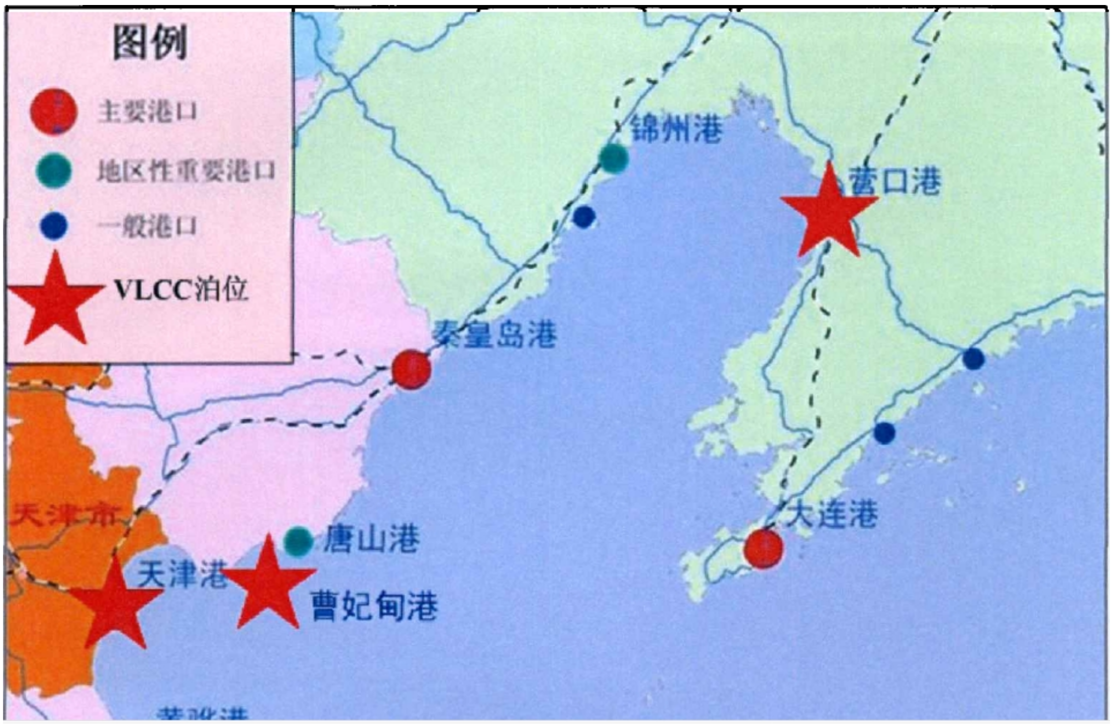

Figure 2- Constructional Situations of VLCC Terminals in Bohai Bay

According to the statistics from Clarkson Company, the international shipbuilding industry consulting authority, by March 2008, there are a total of 498 large oil tankers, among which, 294 are below the age of 10, accounting for 59%, and 402 are below the age of 15, accounting for 81%. By early September 2008, there are in total 263 orders of large-scale tankers around the world. The delivering number in future years will be over 60, which is far exceeding the previous year's deliveries. By April, 2008, there had been 18 large tankers berthing within the Tianjin terminals. From September 2007 to April 2008, the large tankers that arrived at and departed Tianjin Port are listed in the table below. Due to the current shortcoming of key technology, the actual cargo volume of large tankers cannot reach its full volume, which severely restricts its economic benefits.

Table 7- Ship List Arrived at and Departed Bohai Harbor from September 2007 to April 2008 (with Tonnage of about 300,000 tons)

NO.	Ship's Name	Draft （m）	Length （m）	Breadth （m）	Actual Cargo quantity（t）	Fully-loaded cargo capacity （t）
1	Yangtze Star	15.2	321.95	58	12782.71	265995
2	Universal Queen	12.75	333.12	60.04	111949.524	309373
3	Namu	13.5	298.552	60	129750.82	298552
4	Cris	13	334.59	58.05	121688.8	299999
5	Guardians	13.3	332	58	134493	290927
6	Yuanyi Lake	13	333	60.054	120000	298920
7	Champion	12	334.45	58.01	127117.935	299998
8	Raphael	11.85	334	58.05	126727.19	309613.8

9	Suwa	15	327.5	57.237	137927	279984
10	Modern Sun	13.54	330.25	58	129367	299984
11	Modern Flag	13	331	58	131434.945	281074
12	New Golden Ocean	14.8	330	60	172373.817	297376
13	ATOS	14	332.94	60.04	138070.73	298330
14	HAILV 1	14.2	333	60.013	130484.247	299097
15	Francois Shanghai	12.7	333	60.039	132292.304	298971
16	Overseas Mulan	14.4	333	60	167364.023	318518.3
17	Astor	13.15	332	58	96984.894	299222
18	Mearsk nautilus	13.9	332.848	58	130824.446	307284

Source: Tianjin Maritime Safety Administration

3.2 The Natural Self-Cleaning Capacity of Bohai Bay

Bohai is the only continental sea of China, taking an area of 78,000 square kilometers. The Bohai Sea is surrounded by four provinces and one municipality city of Liaoning, Shandong, Hebei and Tianjin, consisting of five parts of Liaodong Bay, Bohai Bay, Laizhou Bay, shallow sea basin and Bohai Strait. As an enclosed shallow sea, Bohai has its innate shortcomings. Experts have proved that it takes 30 years for Bohai Sea to recycle the whole water. “Bohai Sea is an enclosed sea with three bays in it, which makes it a worse self-cleaning capacity.” (Gong & Yang, 1983)

Studies have shown that in the recent 30 years, the pollution area in Bohai Sea has been gradually increasing. The most polluted part is at the northern area of three bays, where the Bohai current is weak (Zhang, 2012). At the northern part of Liaodong Bay there is a counter-clockwise vortex, and two clockwise vortexes at northern Bohai Bay and another one at western Laizhou Bay, which result in seawater exchange deficiency. As deposition of pollutants circuits here, it has become a major pollution area in Bohai Sea.

Bohai Sea is a semi-closed sea. The environmental pollution here is more serious than the open ocean due to exchange deficiency of water. This means that even the same accident, if occurred in the Bohai Sea, the East China Sea or South China Sea, will lead to different consequences. In the CNOOC oil spilling incident, although 840 square kilometers of polluted area had been monitored, it did not mean the scope of the oil spilling would be so big. The environmental fragility of Bohai Sea itself made the impact of the accident last longer and wider, so a close monitoring was needed in a long period (Liu & Zheng, 2004).

Furthermore, since it is close to the mainland, it has to undertake a lot of pollution from the inland. In 2010, the Gross Ocean Production of Bohai Sea region (Liaoning, Hebei, Tianjin, Shandong) reached 1.3271 trillion RMB, taking up 34.5% of GOP in China, surpassing the Yangtze River Delta and Pearl River Delta, and it has become the leading marine economic zone. But the economic development is also accompanied by a large number of pollutants.

Bohai sea area takes an account of about 3% of national waters, but the sewage discharged into it accounted for 40% of the total. The coastal rivers cover densely around the sea. There are 50 rivers and streams, including 19 along the Laizhou Bay, 16 along the coast of Bohai Bay and 15 along the coastwise Liaodong Bay.

2010 China Marine Environment Bulletin shows that standardized discharges into the sea only take up 46% of the total number of monitoring. In the summer of 2010, the area of inferior water reaches 3220 square kilometers. The regional distributions of major pollution are in the Liaodong Bay, Bohai Bay, Laizhou Bay. The area of unqualified water also expanded from 20,080 square kilometers in 2006 to 32,730 square kilometers in 2010, growing by more than 60% in five years.

3.3 Pollution Prevention and Cleaning Capacity Analysis

3.3.1 The Ability of Responding to Emergencies.

Tianjin Maritime Safety Administration has been working on this ability, and already built its basic fast-respond system of anti-pollution. However, the anti-pollution ability that Tianjin port possesses literally is merely able to deal with oil-spilling cases under 200 tons. Thus, in a nutshell, this rapid development requires higher level of ability of responding to emergent incidents, but this level is far higher than Tianjin port currently has.

3.3.2 Unprofessionalism of Fast Response Crew.

Though Tianjin Port gained colossal support from Tianjin Maritime Safety Administration, it has only built one professional cleaning squad, not to mention other organizations, except that CNOOC has a decent team, other 3 companies' personnel are fairly unprofessional. So, generally speaking, crews working for this purpose are not professional and can not work for those serious incidents for sure, and the expense of utilizing those anti-pollution equipments is also a considerable amount.

3.3.3 Measurements of Survivance.

Currently, as the major supervising agent— Maritime Safety Administration is not capable of monitoring the entire ocean environment, the temporary issues Maritime Safety Administration has are mainly represented in primitive methods, and partial supervising, which adversely affects the accuracy and timing of the response.

3.3.4 Lack of Governmental Fundings

The establishment of fast responding ability establishment needs huge amount of governmental funding. However, transportation department can hardly cover half of its expenses, thus in China there are only two official bases, one at Chengshantou, the other at Beidaihe, which has just been built up and is now under the direct-commands from the prime minister. Besides, according to the current economic condition, the transport department is not able to invest enough fund to set up a new base around. Therefore, local government has to make much effort in helping this fast responding equipment storage bases. Through decades' of work, and cooperation with relative departments, Tianjin Maritime Safety Administration has figured a way in holding this base, and also getting ready to finish this propose off in following years.

3.4 Pollution Hazardous Evaluation

Table 8- Major Environmental Risk Types in Tianjin Port

Risk Types	Risk Factors	Reasons of Risk	Frequency	Hazard
Oil or Chemical Spills	oil or chemical spills at sea	By the ship collision, misuse, artificially discharged, ship malfunction, etc.	Small	Large
	oil or chemical spills in the quay	Mainly caused by the pipe joints leakage and misuse	Middle	Small
	oil or chemical spills in tanker field	Mainly caused by the pipe joints leakage and misuse	Small	Small
Fires	Fires at sea	Mainly caused by human factors	Small	Middle
	Fires in the quay	Mainly caused by human factors	Small	Small
Explosions	Fires in tanker field	Mainly caused by human factors and lightening strokes	Small	Large
Red Tides	Tanker field	Mainly caused by fires	Small	Extremely Large
	Overproduction of red tide organisms	Eutrophication, hydro meteorological situation and the change of physical	Middle	Middle

		and chemical factors of sea waters		

Pollution from the inland has almost crushed the resilience of Bohai, so any pollution from the offshore development nearly ruins the last ditch effort. Nowadays, oil wells are booming, and leakage accidents occur at frequent intervals. Since accidents have occurred in such a frequent manner, lots of them are chosen not to be reported or whitewashed. In addition, Bohai is the pivot of inland and Pacific Ocean, at least 600 to 700 ships sail by everyday, and incidents like collision, leakage, drowning take place. Thus, the oil spots found around Chang Island will also be found in summer, however, incidents like this are usually not worthy to report.

National Oceanic Administration released *China Oceanic Environment Condition Report 2010,* which revealed that, during the 11th 5 years' plan, oil development has been enlarging, and numbers of bases grew one time larger than before. Subject to data, in 2010, the numbers of platforms grew up to 195.

According to National Oceanic Administration, during 1977 to 1996, there were totally 2353 oil-spilling incidents in coastal area of China, almost once every four days in average. The total oil leakage exceeded 30,000 tons. From 1998 to 2008, 733 pollution incidents happened in Chinese jurisdictional sea. The possibility of Oil leakage risk of submarine pipelines in Bohai Bay is 0.1 times per year, and the possibility of that of platforms is about 0.2 times per year.

With the development of submarine oil exploration of our country, the oil spilling incidents may increase. Until December 31, 2010, the annual production of

CNOOC achieved 51.78 million tons, and the Bohai Bay contributed more than 30 million tons. Bohai Bay has become the base of Chinese oil exploration.

According to statistics from CNOOC, until the end of 2010, the accumulative total discovery of original oil reserves in Bohai area had reached 4.5 billion cubic meters (Wang, 2012). According to media report, the submarine oil resource in Bohai Bay is approximately 7.67 billion tons, natural gas 1,000 billion cubic meters. That is to say, the proved reserves now are half of the total.

In 2010, red tide occurred seven times in Bohai Sea, reaching an area of 3560 square kilometers. Besides, on October 11 and 12, 2010, for the first time we discovered toxic red tide in Bohai Sea.

Some experts said that this was related to oil spilling incidents. Because oil itself is rich of nitrogen, phosphorus and other organic ingredients, the degradation of it will cause the eutrophication of local waters, leading to red tides. This is not the only hazard of oil spill. After oily waste water or oil getting into the sea, the water-soluble components can poison fish or even kill them, while film attaches to the gills of fish and prevents its normal breathing, causing a large number of biological poisoning and death. Oil will also attach to the phytoplankton to prevent its photosynthesis effect, reducing bait basis in the water, causing damage to the entire ecosystem, breaking the existing ecological balance (Tu, 2005).

More experts said the oil is rich of aromatic hydrocarbons, which can convert into more toxic substances in mammals or birds, thus affecting their NDA. These DNA mutations can cause fertility degeneration or even cancer of animals.

The annual output of shrimp was about 40,000 tons previously in Bohai, but because that water pollution destroyed the spawning grounds, from 1993 on, a wide range of shrimp spawning disappeared. In three consecutive years from 1995 to 1997, a large number of scallops died in Changdao County, causing a lost of hundreds of millions of Yuan a year. That is also the time of mass offshore oil and gas exploration, when the oil content in some water area doubled more than 1,000 times.

4. Risk Prediction Evaluation of Large Tanker's Maritime Environmental Influence to Tianjin Port

4.1 Methodology Review

The offshore oil spill Maritime Environmental Risk Evaluation is an assessment of emergent oil spilling incidents of ships that arrive in and depart the port. Environmental risk evaluation is mainly used in the field of nuclear facilities previously. For water areas, especially the environmental risk evaluations of ship oil spill, it is rarely used. This paper attempts to identify and describe the accident hazards, analyze under what circumstances an unexpected accident may occur, and estimate the probability of accidents and the severity of the adverse consequences and harm range, and finally have an assessment on the consequences to formulate emergency environmental protection plans and guides, providing a scientific basis for decision-makers. The method used in paper is to estimate the probability of oil spilling.

Many ways can be applied to estimation of the probability of an accident in environmental risk evaluation, such as mathematical statistics method, analog simulation method, and formula calculation method. However, to some assessments of potential large disaster risks, because it has a low probability of less than 10^{-6} times per year and its impact is catastrophic, regional and destructive, such as the Chernobyl nuclear accident of the former Soviet Union, normal statistical approaches are difficult to achieve the goal. Usually we use the method of fault tree analysis (FTA), which not only applies to both the qualitative analysis, but also the quantitative analysis, with a wide range of applications scope and simple image, at the same time systematic, accurate and predictable. Therefore FTA is a scientific and advanced method for safety analysis and accident prediction, which has been recognized and widely adopted. Now we use the environmental risk evaluation method to calculate the maximum probability of occurrence of the top accidents, and assume the consequences (Sun, 2009).

4.2 Statistics and Incident Probability Analysis of Large Tankers

While at sea, the collision probability of ships is generally very small. Therefore, the probability of an accident at sea obeys discrete binomial probability distribution. Here we will make a calculation of ship accidents probability of Tianjin Port.

Let us assume the traffic volume in this area is n, K times of incident occurred, the probability of the risk of accidents is:

$$P = (x = k) = C_n^k \bullet p^k \bullet q^{n-k} \ (1)$$

In equation (1), p is the accident probability of each ship, the basic value of risk probability for ship accidents study. q = 1-p is the risk probability that each ship does not have an accident.

Tables 9 and 10 are respectively the traffic volume and the number of oil tankers in Tianjin Port from 2003 - 2008

Table 9- Traffic Volume in Tianjin Port of Different Levels of Tonnage in 2003-2008

Year / Tonnage	03	04	05	06	07	08	Total	Proportion
Total	33592	33608	33173	32795	32851	32691	198710	33118 （Average）

Below 499	12238	11252	10608	9321	8810	7929	60158	30.3%
500-2999	11821	12906	11991	11076	10161	9926	68881	34.7%
3000-9999	6585	7128	7859	8821	9403	9958	49756	25.0%
10000-19999	2066	1359	1658	1947	3210	3418	13658	6.9%
20000-39999	680	753	794	801	942	1096	5066	2.5%
40000-59999	185	198	221	234	249	261	1348	0.67%
60000-99999	17	12	41	70	37	62	239	0.12%
100000-199999	0	0	1	25	39	41	105	0.05%
200000-299999	0	0	0	0	0	3	3	0.0015%

Table 10- The Number of Tankers of Different Tonnages that Arrive at and Depart Tianjin Port in 2003-2008

Year / Tonnage	03	04	05	06	07	08	Total	Proportion
Total	4045	3410	4111	4864	5278	5006	26714	4452（Average）
Below 499	528	693	372	751	835	359	4038	15.1%
500-2999	2683	1927	2846	3109	3373	3056	16994	63.6%
3000-9999	496	518	549	676	651	708	3598	13.5%
10000-19999	153	117	138	164	189	177	938	3.5%
20000-39999	175	143	196	157	214	203	1088	4.1%
40000-59999	10	12	10	7	16	9	64	0.21%

60000-99999	6	0	0	9	12	16	43	0.16%
100000-199999	0	0	0	3	3	9	15	0.0056%
200000-299999	0	0	0	0	0	0	0	0

According to the statistics in the table 9 and 10, we can assume that in the next S years, n=33000·S ships will arrive at and depart Tianjin Port, and at the same time the confidence coefficient of not having an accident in this area is 95%.

So from (l) we can get:

$$P(k \geq 1) = \sum_{k=1}^{n} C_n^k p^k (1-p)^{n-k} \leq 0.95 \quad (2)$$

$$P \leq 0.908 \times 10^{-4} / s$$

So the basic value of accidental risks probability in future in Tianjin Port is: $P \leq 0.908 \times 10^{-4} / s$.

4.3 Prediction of Risk Probability of Emergent Oil Spilling in Tianjin Port

Assume that oil tankers that arrive at and depart Tianjin Port take a proportion of R in all the ships. To be simple, we assume that in all the navigating tankers, half are loaded and the other half are empty. The probability of having an oil spilling incident after collision is 50% (Xia & Shi, 2000).

Here we just take the collisions, the groundings and hull damages into consideration yet ignore other kinds of accidents. Besides, we neglect single-ship accidents and two-tanker accidents.

(1) Oil spill from collision

In shipping lane and anchorage, a necessary condition for collision and oil spilling is: there must be one oil tanker with crude oil loaded.

P1 (two ships are both empty oil tankers)

=P2 (one of them is an empty tanker or it is not a oil tanker)*P2 (the other one is also empty or not an oil tanker)

P2=P3 (empty tankers) +P4(loaded tankers)

=R/2+ (1-R) =l-R/2

So:

P (at least one loaded tanker in the two) =1-P_l=1-(l-R/2)^2

=R (l-R/4)

According to the assuming condition:

P (collision in shipping lane)=P(collision in anchorage)

$$=(\frac{1}{3}p)\bullet R(1-\frac{R}{4})$$

P (collision at berth) $=(\frac{1}{3}p)\bullet \frac{R}{2}$

So

P_{total}(oil-spilling|collision)= $50\%\times[2\times(\frac{1}{3}p)\times R(1-\frac{R}{4})+(\frac{1}{3}p)\bullet\frac{R}{2}]=\frac{1}{12}pR(5-R)$

(2) Oil spill from grounding

The grounding incident can occur with only one ship, so

P(grounding in shipping lane)=P(grounding in anchorage)

=P(grounding at berth)

=P/3

Since the empty tankers and loaded tankers take R/2 respectively

So P(oil-spilling|grounding)= $50\%\times\frac{R}{2}\times(\frac{p}{3}+\frac{p}{3}+\frac{p}{3})=\frac{1}{4}pR$

(3) Oil spill from hull damage

Hull damage of oil tanker can also lead to a oil leakage with only one ship, which can take the same way of calculation like grounding.

P(oil-spilling|hull damage)= $50\% \times \frac{R}{2} \times (\frac{p}{3} + \frac{p}{3} + \frac{p}{3}) = \frac{1}{4} pR$

The risk probability of accidental oil leakage of oil tankers refers to the total of the probability of collision, grounding and hull damage, so

P(oil-spilling)= $\frac{1}{12} pR(5-R) + \frac{1}{4} pR + \frac{1}{4} pR = \frac{11-R}{12} pR$ (3)

According to Table 9 and Table 10, we can assume that in all the ships that get in and out of Tianjin Port in future; the oil tanker takes 12%.

So in the next S years, the oil spilling risk probability of Tianjin Port is:

N(the number of oil tankers)*P(oil spilling)

= $12\% \times 33000 \times S \times \frac{11-12\%}{12} \times 0.908 \times 10^{-4} / S \times 12\%$

= $0.469/12 = 0.0174 \approx 0.039 \approx 1/25$ times per year

Obviously, as the proportion R increases, the leakage risk probability will grow accordingly.

4.4 Analysis of Possible Spillage in Oil Spill Accident in Tianjin Port

The oil leakage of Accidental oil spilling is pretty huge, and how much the leakage is depends on the place and the severity of the damage. According to its different tonnage, an oil ranker can usually be divided into from several to over twenty tanks, which have various volumes. Normally the middle tanks are larger than the side tanks, head tanks and tail tanks. An oil tanker with 5000 tons of tonnage usually has nearly 10 cargo tanks, with 500 cubic meters each one. Tanker with 10,000 to

20,000 tons of tonnage may have 20 cargo tanks, with 3000-5000 cubic meters each one for average.

The largest leakage of a single accident is the leakage of all the cargoes in the ship, while this kind of circumstance happens at an extremely low rate. In most cases, only a part of oil spills into the sea. For instance, in accidents like collision, grounding and stranding, there will be usually one or two damaged cargo tanks, with part of the cargo leaking out. In 26 serious oil-spilling accidents in our country from 1973 to 1994, the largest accidental leakage belongs to Nanyang Vessel, with an oil leakage of 8000 tons, taking up 30 percents of its tonnage. For other several events, the volumes of leakage all take up less than 10% of their tonnage, 2.5% on average.

According to Table 10, we can divide the ships that come in and out of Tianjin Port into three categories of small-scale oil tankers below 3,000 tons, middle-scale tankers between 3,000 tons and 100,000 tons, and the large-scale tankers above 100,000 tons. They take up the proportion of 78.6%, 21.35% and 0.006% respectively. Assume that the oil leakage in 10% of the total tonnage of the ship after an accident, thus the leakage of small-scale tankers is below 300 tons, the middle-scale tankers is between 300 tons and 10,000 tons, and the large-scale tankers is above 10,000 tons. Therefore, we can have a brief analysis on the risk probability of different types of tankers.

(1) Risk probability of leakage below 300 tons

From (3) we know:

P (oil leakage) = $\frac{11-R}{12}pR = \frac{11-R}{12} \times 0.908 \times 10^{-4} / S \times 0.1$

$=8.25\times10^{-6}/S$

So

P (oil leakage|<300 tons)= n(the number of tankers with tonnage below 3000 tons) • P (oil leakage)

$=(12\%\times33000\times S)\ \times78.6\%\times8.25\times10^{-6}/S$

$=0.026\approx1/40$ times per year

2) Risk probability of leakage between 300 and 10,000 tons

P(oil leakage|300-10,000 tons)= n(the number of tankers with tonnage from 3,000 to 100,000) • P(oil leakage)

$=(12\%\times33000\times S)\ \times21.35\%\times8.25\times10^{-6}/S$

=0.007=1/143 times per year

3)Risk probability of leakage above 10,000 tons

P(oil leakage|>10,000 tons)= n(the number of tankers with tonnage above 100,000 tons) • P(oil leakage)

$=(12\%\times33000\times S)\ \times0.006\%\times8.25\times10^{-6}/S$

$=2\times10^{-6}$=1/500,000 times per year

According to the risk evaluation equation, Risk=Probability × Consequences, we can calculate the oil leakage risks of these three kinds of ships respectively:

Risk for small-scale tankers: 1/40 times / year $\times\frac{300}{2}$ tons=3.75 ton times/ year

Risks for middle-scale tankers: 1/143 times /year $\times\frac{10000+300}{2}$ tons=36 ton times / year

Risks for large-scale tankers: 1/500,000 times / year $\times$ $\frac{30000+10000}{2}$ tons=0.04 ton times / year

From the calculation above we can see, the oil leakage risk for ships with a tonnage between 3,000 to 100,000 tons is the highest. Comparatively, even though large-scale tankers with a tonnage above 100,000 tons could have an astonishing leakage in a single accident, its leakage probability is very small, thus have the smallest leakage risk among the three ship types.

5. Study on Safety Strategies of Large-scale tanker

5.1 Increasing Infrastructure Investment in Tianjin Port

5.1.1 Construction of Vessel Pollution Preparation Infrastructure in Binhai New Area

According to the second paragraph of Article XVII of *Marine Environmental Protection Law of People's Republic of China*, "Coastal local governments above the county level administrative region in the coastal waters of the serious contamination of the environment must take effective measures to remove or mitigate harm". (Marine Environmental Protection Law of People's Republic of China, 1999)

This paragraph is intended to strengthen the sense of responsibility of the local people's governments above the county level for the sudden serious pollution accident hazards along the coast.

Nowadays, a lot of local governments have take measures, such as Qingdao government, facing the risk of Pollution in Qingdao port, decided to invest more than sixteen million RMB Yuan to strengthen vessel pollution preparedness infrastructure. Therefore, the author proposed to bring ship pollution response equipment storage in Binhai New Area Government into Tianjin emergency system construction plan and provide special construction funds for the construction of Binhai New ship pollution response equipment storage (Miao, 2008).

5.1.2 Construction of 500,000 Tons Emergency Equipment Storage

Emergent equipments and backups in emergence equipment storage mainly aim to respond to emergent situations along coastline. Currently the standard of preventing is supposed to be enforced to every port so that they can take care of any leaking accident under 500 tons of oil (Chen, 2009). Basing on the location of ports, the builder ought to construct in proper spots under the principle of making transportation easier, faster in Binhai new area, and the locations are suggested to be around Lingang harbor industrial zone, which is under the administration of both Maritime Safety Administration and Dongjiang fast response base.

5.1.3 Construction of the Operational System of Sustainable Emergency Equipment Storage

Emergence equipment storage cannot work without the funding from government, reasonable marketing, and it is required to benefit the citizens, as well as enforcing its mandatory repayable service (Li, 2000). According to other successful instances from different provinces and cities, government shall investigate the building of oil spill fast responding. Also the fees of daily operation ought to be earned under the execution of operating under free marketing, unless the compensation from emergent incidents, besides, any other fees will be covered by the transportation department. Specifically, Tianjin Maritime Safety is in charge of daily operating, drills of emergent responses and periodical training, in order to make it the major power of vessel pollution response.

5.2 Strengthening the PSC's Supervision of Large Tanker

Inspection and administration of large scale ships include setting and practicing the regulations that make ships go through in specific orders, area, routes and let ships report in certain place so that their speed can be controlled, and proper lots can be arranged for them to park in. These regulations and combos of amendments, to some extent, will diminish the potentiality of oil-leaking and clear the routes, so sailing can also be secured.

5.2.1 Definition of Ships' Priority

For those ships going through Bohai port, its priority of importing and exporting will be arranged by the pre-designing and basic transporting logic. In Tianjin enhancing routes, there are several types of ships, in terms of their sizes, categories, characters, speeds, directions and destinations (Wu, 2009). For the purpose of securing transporting safety and improving traffic on ocean, people may focus on working out two issues: First, making sure large vessels will be put at the first place of using deepwater fairways. Second, whenever large scale oil tankers encounter other ships, large scale oil tankers have the priority of getting through first. Maritime department ought to work out certain regulations to secure this priority.

5.2.2 Ship Routing

In the consideration of insufficient depth of water around Tianjin port, for clearing large scale oil tankers' routes in deepwater fairways, also diminishing occurrences of strands and striking reefs, people shall practice under the suggestions below, which is based on the purpose, definition, procedure, responsibility, measurements, standards, and temporary adjustment from *Ship routing standards*.

1. Ships sail on the recommended routes may navigate at right side of the mean line, and the distance from the mean line is suggested to be at least 0.5n mile.
2. Ships may drive meticulously when importing and exporting by itself.
3. Dropping anchors, fishing, breeding or any offshore engagements among the precautionary area, inside recommended mean line's 1.5n mile zones are forbidden.
4. Any ship navigate on the enhancing routes will not exempt from the

responsibilities and obligations in *International Regulations for Preventing Collisions at Sea*.

5. Ships violate this regulations will be disposed under local laws, so will the personnel on those ships be.

5.2.3 Emergency Anchorage of Large-Scale Oil Tanker

Large scale oil ships' emergent anchorage is the appointed water that large scale oil tankers can drop anchors, slow down or drift for not getting into the ports temporarily. The purpose of making an emergent anchorage spot is to help those ships that cannot get inside port for whatever reason to settle in a place so as to prevent stagnations, protect marine environment, and enhance transportation. In 2008, Tianjin maritime safety administration issued *Bohai Shipping Routing* (Shao & Ju, 2009). In that file, it points out Caofeidian and middle Bohai area are the spots for emergent anchorages, and only large scale oil tankers can be parked here. The specific coordinates are among:

38°49.0N, 119°20.0E; 38°49.0N, 119°27.0E

38°46.5N, 119°27.0E; 38°46.5N, 119°20.0E

The entire area for emergent anchorage is 13.75 nautical miles square, and the depth is 25-26m, and also the substrate is filled with mud. This area is 66 nautical mile from Laotieshan, 35 nautical miles from Caofeidian. (Bi, 2009)

5.3 Improving the Maritime Supervisory Pattern

5.3.1 Building Unified Maritime Countermeasures of Meteorological Disaster

Procuring accurate hydrology, geography, weather information is the premise of executing safety patrols, especially for the administration of large scale oil tankers. Thus professional meteorology observatory, radio station, ocean station and networks are built for acquiring hydrology, weather information in order to analyze and evaluate out practical defending measurements. Besides, periodical and timely dispatching will serve maritime administration and coastline responses well so that large scale oil tankers will sail safely with the help of meteorological and hydrological information.

5.3.2 Building a Cruise Team

In fact, in the area that VTS does not cover, ships are watched over under the patrols. However, most patrols are quite small and the total amount of them is very scanty. The largest patrol in Tianjin Maritime Safety Administration is 45m ship, but patrols that meet that requirements in Tianjin are only Bohai patrol 051 and Bohai patrol 052; and Bohai patrol 0501, Bohai patrol 0503, Bohai patrol 0504 are smaller than the previous two (Qu, 2010). This amount of patrol is apparently insufficient to cover the intimidating huge Bohai water. For fulfilling the ultimate goal from the Eleventh Five-Year Plan which elaborated on the necessity of monitoring the whole water, operating in any weather, and fast responses, it also requires that the crews arrive at certain area within 150 minutes if the spot sends the signal no further than 50n miles. Furthermore, the entire ratio of successful succors is expected to be higher than 93%. Thus, Tianjin Maritime Safety Administration shall equip relative departments' updated patrols from 45m-60m so that the ability of fighting against incidents can be strengthened.

5.3.3 Formulating a Complete Emergency Response Plan

Through the analysis and conclusions of past incidents that ever occurred with large oil tankers and other emergent response experiences, people shall establish and perfect long-term emergence response rearrange plans, set up standard drill, training, rehearsal, and evaluation system, so that most of potential incidents can be prevented and effectively controlled.

6. Conclusions and Prospects

So far we can get our conclusion that the maritime environmental influence of large-scale oil tanker is positive to Tianjin Port. The promotion of ship-upsizing is beneficial to reduce the oil leakage risk. But at the same time we should see that, since the leakage of large tanker will cause catastrophic result to the regional environment, we need to pay more attention to the navigating safety and the warning mechanism of large-scale oil tanker while promoting it.

Due to the complexity of navigation safety of large-scale oil tankers in Tianjin Port, as well as the limitation of previous study, although this paper used some actual data and relevant resources to have a deep research and analysis, it is still only some of the pioneering and exploratory work with many inevitable shortcomings and drawbacks, and the result is only basic and preliminary, where there are still many places worth a further discussion. I hope this research can become a start in the future in some deeper and further studies. Problems deserving a further study include:

(1) The differences between the probabilities of an oil spilling event of large tankers in different carrier conditions, different storm conditions and different regions in the waters of Tianjin Port.

(2) A further improvement of Maritime Joint Supervision Mechanism of large tankers.

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