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Analysis of spilled oil pollution in Qingdao port

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Analysis of spilled oil pollution in Qingdao port

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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: **Analysis of spilled oil pollution in Qingdao port**

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With the development of China's economy and oil industry, oil transportation is growing rapidly. At the same time, oil spill accidents occur frequently, not only caused huge economic losses, but also to the marine ecological environment caused great harm. So taking effective measures to prevent and control oil pollution, which has a great significance for the normal operation of the port and the protection of personal and property security.

Qingdao port, one of the big ports in China, and the throughput of imported crude oil is the first in china. In recent years, along with the continuous expansion of terminal, the expansion of production and transportation of crude oil, Qingdao port has become a high-risk areas of oil spill accidents. The frequent occurrence of oil spill in Qingdao caused a great loss, so research on the harmful caused by the oil spill accident, provide reasonable measures for prevention and control, to minimize the loss of oil spill pollution accident, has an important theoretical significance and application value.

In this thesis, the oil pollution accidents of ships in Qingdao sea area are taken as the object of study. This thesis analysis the natural environment and infrastructure environment of Qingdao port. Then, collect the number of oil spill accidents occurred in Qingdao port, and analysis the cause of spilled oil accident in Qingdao port and its influence on port. And through multiple regression model, quantify the economic losses caused by oil pollution to the port. According to the results obtained, put forward corresponding suggestions to prevent and control measures of oil spill in Qingdao port.

KEYWORDS: Oil spill, Spilled oil pollution, Qingdao port, Regression analysis, Hazards and control measures of oil spill

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Chapter 1 Introduction

1.1 Background

In modern society, oil has become an important resource. All countries have a large demand of imported oil, so with the increasing demand for oil, the frequency of oil pollution accidents in the port is also rising. According to The International Tanker Owners Pollution Federation statistics of the global tanker oil spill accident data can be seen (Appendix 1,2,3,4)，from the beginning of 1970，seaborne oil trade boom has led to increased risk of oil spill. Most of the small and medium spilled oil accident was happened in the process of loading and unloading cargo at ports and docks. Major spilled oil accident mainly occurred in the navigation, mainly caused by stranding and collision. These oil spill accidents have brought serious economic losses to ports in different countries.

In China, shipping is the most common and economic way of oil transportation. Most of the oil imports were finished by sea. Surging demand for oil, the oil tanker is more and more tend to be large, thus increase the possibility of oil spill accident to the port and nearby area.

Qingdao port, one of the big ports in China, crude oil throughput of the ports in China is first. In recent years, along with the continuous expansion of terminal, the expansion of production and transportation of crude oil, Qingdao port has become a high-risk areas of oil spill accidents. For ports and sea, if occur spilled oil accident, the area will face the problem that is clear difficult, pollution area is big, easy to spread. If government not take timely measures, it will cause serious marine pollution. So oil spill pollution problem has become a worldwide problem, it is urgent to understand the dangers of oil spill pollution and prevent the environment of port.

1.2 Objective

The main purpose of this paper is to analysis the spilled oil pollution in Qingdao port and its impact on port (economic loss), so that people can fully realize the harm of oil spill pollution. The second is put forward scientific and rational defense methods and measures to solve oil spill in Qingdao port, so that we can control of the oil spill effectively and timely clearance, protection of port and ocean ecological environment.

In order to achieve this goal, in this article, firstly collect the data of oil spill accident happened in Qingdao port, by sorting and statistics of the data, determine the specific conditions of the accident, such as the oil spill location, the cause of accident, etc. Using regression model to analysis the harmful of oil spill accident to the port(economic loss). Finally, according to the results obtained, this paper puts forward some suggestions for preventing oil spill and oil spill in Qingdao port, which can provide reference for the sustainable development of the future.

1.3 Methodology

The main purpose of this article is to study and analysis of spilled oil pollution in Qingdao port and its impact on port(economic loss), in general, oil spill pollution is lead to direct economic loss to port. Such as, wharf berthing area is polluted, it need to clean waters thereof, will inevitably affect the clearance of the ship and the port production efficiency. And by ship pollution cleaning is also expensive. These economic losses are hard to use simple data to measure. In the long term, it will cause damage to the ecological environment, tourism and so on.

Therefore, in order to determine the harmful of oil spill accident and quantify the economic losses, this paper will mainly use statistical and regression model. By build three variables "the amount of spilled oil X_1" " the length of polluted coastline X_2 ""oil spill diffusion time X_3" are used as independent variables to study the effects of these

variables on economic loss (Y).The result indicated that "the amount of spilled oil X_1" " the length of polluted coastline X_2 ""oil spill diffusion time X_3" respectively on the explanatory variables " have a significant impact to the amount of loss of Y.

1.4 Outlines of the dissertation

The purpose of this paper is to study the causes of oil spill in Qingdao port and the impact of spilled oil pollution on the port. And using multiple regression method, select a number of independent variables, establish a regression model to measure the specific impact of oil spill pollution on the port. Therefore, this article's structure is as follows, the first chapter and second chapter will introduce the background of the article and literature review. The third chapter mainly elaborates the basic conditions of Qingdao port, including the basic situation of port and terminals, climate environment, navigation conditions. The fourth chapter is collect and sort out the data about oil spill accident, and analysis the oil spill accident in Qingdao port. In the fifth chapter, will analysis the cause of oil pollution accident in Qingdao port and its harm to port. In the sixth chapter ,by using regression model, determine the economic losses caused by oil spill pollution to the port. In the chapter seventh, according to the results, putting forward corresponding suggestions and preventive measures for the port.

This study could be a reference for oil spill pollution control in Qingdao port , and provide reference for the development of other ports.

Chapter 2 Literature Review

The theme of this paper is to study the impact of oil spill pollution on Qingdao port, so this paper will review the past research on oil spill. The literature review will be divided into two parts, the first part is about the domestic and foreign relevant laws and regulations on oil spill pollution, the second part is the domestic and foreign experts and scholars for oil spill research results.

2.1 Relevant laws and regulations on oil spill pollution

In the early days of the first World War, western countries were aware of the seriousness of the problem of oil pollution, and took some preliminary measures. After the end of World War II, western countries began to enact international regulations and agreements to prevent pollution caused by ships. Therefore, western countries, such as Europe and the United States, in the prevention of ship pollution regulations are relatively perfect.

In 1954, an international conference was held in London. Britain, France and the United States, more than and 20 marine countries to participate in this meeting. It adopted the first international regulation to prevent oil pollution of the sea , which is *International Convention for the Prevention of Pollution of the Sea by Oil* (OILPOL1954), the convention focus on decreasing the daily operation of ship pollution, this regulation played a positive role to prevent oil pollution. But the Convention has some limitations, It only sets up a restricted area of oil only within 50 miles of land area, did not make restrictions to sea oil discharge from outside the area, if these area happen an oil pollution accident, it will cause serious consequences.

In 1967 the Torry Canyon tanker leak, led to the leakage of about 110,000 tons of crude oil , seriously polluted the coast of United Kingdom, France. The oil spill incident

not only let people realize the harmfulness of oil spills, but also let all countries recognized the urgency to set up pollution regulations. So in 1969 formulated *International Convention Relating to Intervention on the high Seas in Cases of Oil of Oil Pollution Casualties ,1969* (CSI1969), this target is to prevent and reduce the occurrence of oil spill.

And in order to get the corresponding compensation for oil pollution victim, it formulated *International Convention on Oil Liability for Oil Pollution Damage,1969* (CLCI1969),the Convention safeguard the rights of the oil pollution victim .Since then, has introduced the prevention of pollution by international regulations. So the prevention of pollution by vessels in west is relatively complete comprehensive international regulations. Since then, because of more and more ship pollution incidents happened in the various countries, more and more countries set up laws and regulations about prevent pollution of ships. Therefore, the international laws and regulations on the prevention of pollution from ships in western countries are relatively complete.

Compared with foreign research results, in china, because China industrialization later than the west, so China research on oil spill pollution problem started late, did not form a complete research system and method, but with the development of science and technology in China in recent years in the research of oil spill pollution problems have also made significant progress.

In 1982, the Standing Committee of the National People's Congress promulgated *People's Republic of China marine environmental protection law*, the purpose is to protect and improve the marine ecological environment, decrease pollution to maintain the balance of ecological environment. And in 1983, for prevention and control of vessel pollution of the sea, it formulated *People's Republic of China Management Ordinance* to prevent ship pollution, the regulations formulate the oil operation and oil wastewater discharge standards, strengthen and perfect laws of oil pollution.

2.2 Research status of spilled oil pollution

In foreign countries, Devanney (1974) used Bayesian formula to analysis datas of oil spill accidents ,studied the probability characteristics of spilled oil accident. Because of some waters no record of oil spill accidents, the data is not complete, so the method is not accurate. The United States DOI development model oil spill risk (OSRA), the model can simulate the oil spill trajectory, the principle is as follows: at a given time and given place to affect the oil spill sensitive areas of the condition as the conditional probability, and then use the Poisson distribution to calculate the oil spill based probability, finally obtains the comprehensive probability of oil spill impact of environmental resources.

Robert H.Schulze(1983) through studied the relationship between the ship's flux and probability of oil spill, study, analyzes the influence of visibility on tanker accident, and gives the probability of oil spill accidents occurred in the region. This is the method to obtain the probability of oil spill through the conditional probability, which has been applied in practice.

Holland scholar W.Kppos (1990) putted forward the evaluation model of oil spill pollution grade. Based on the model, 9 indexes are used to analyze the possible pollution caused by oil spill accident, and measure the degree of harm after oil spill. However, the model is based on the characteristics of oil to evaluate the extent of oil spill pollution, and does not consider the location of the accident, the ship's condition and other factors.

Japanese experts Sergey (2000) used the particle tracking model to simulation of the oil spill process in the sea of Japan with regional ocean circulation model. This study combines the random diffusion, the convection of the ocean, the buoyancy effect and other factors, and forms the local ocean circulation model. In addition, in this study, the parameters of oil evaporation, drift, diffusion, biodegradation and oil weathering were also parameterized, summarizes in the oil spill accidents, the change process and trend of oil 's trajectory , further refined oil spill model.

Eide (2007) proposed a new dynamic environment risk model. The model predicts the environmental risk of oil tanker accidents. At the same time, the influence probability of oil spill on coastline is simulated. The results show that the model can effectively judge the risk level.

In addition, Oil spill risk assessment becomes more and more important, the international society has discussed the theory of probability method, artificial neural network method, analytic hierarchy process (AHP), grey prediction method in the application of the spilled oil accidents. In 2000, Australia was assessed on the coastal marine pollution risk; subsequently, New Zealand also follow its carry out risk assessment; the United States, Canada based on the theory of risk management to evaluate the sea oil spill risk and coping ability. In 2004, the International Maritime Organization of Marine Environment Protection Committee adopted the proposals submitted by Russia, set up a special working group to compile guidelines for the oil spill risk's evaluation.

In China, with the increasing attention to the problem of oil spill, some scholars have made a corresponding study on the problem of oil spill pollution.

Zhou Lixin, Yang Fan, Yang Changzhu (2005), through the research on the technology of oil spill prevention and control, it is concluded that the oil spill in the future will be dominated by a large oil spill, and the marine oil pollution will become more and more serious. And It is a big challenge for China's marine ecological environment.

Ning Tingdong (2006) studied oil spill damage by using fuzzy comprehensive evaluation method ,determined the hydrological conditions, pollution and other factors will affect the oil spill. In addition, setting up the oil spill damage assessment model , and putting forward assessment technology for the general procedure and oil pollution accident.

The domestic scholar Shixin, Zhangxin(2007)， Using correlation method and BP neural network, assess harm grade for the oil spill accident in Shanghai port, to identify the advantages and disadvantages of different evaluation methods, the results show that

the BP neural network and correlation method has good applicability, and the error rate of BP neural network is less low than others, but there is a shortcomings that the cost of build model is highly.

The domestic scholar Zheng Jianzhong, Wang Jing, Wang Xiaoyan(2008) focuses on the different types of coast oil spill cleanup methods, the results show that the correct oil spill cleanup plan should consider the coast sensitivity index, oil spill type, cleaning method may bring harm as well as the actual operation level etc. Including the salt marsh and coastal mangrove coast, coastal deposition of typical coastal domestic and foreign existing marine oil spill pollution cleaning technology are discussed in detail, providing a reference for oil spill contingency plan for China's coast.

Liu Wei (2008) considered that the hazard assessment of marine oil spill is a multi attribute classification problem. Based on the analysis of the oil spill accident, established a mathematical model to analysis and verification the harm of ship oil spill.

Wang Chuanyuan, He Shijie (2009) by analyzing the current situation of China offshore oil spill pollution, thinks that oil imports continued to grow, loading and unloading of oil and maritime transport and port frequently is caused in the coastal oil pollution spill. And discussed the marine oil spill pollution harm to ecological hazards, putted forward the countermeasures and methods of prevention and treatment

Liu Jie, Jia Yonggang, Gao Zhenhui (2010) have studied the high offshore oil spill pollution problems, the article first established offshore oil platform evaluation index system of oil spill pollution. Using the analytic hierarchy process (AHP) to calculate the weight of each index, and using the amount of oil spill and persistent oil as an example, establishing oil spills and oil characteristics of membership function persistence subset of the membership table, final finished the model of comprehensive evaluation of oil spill pollution .

Cui Yuan, Zheng Guodong (2010) through the analysis of oil spill on the sea, proposed the establishment of a database system and risk assessment of oil spill risk source, to strengthen the management of oil spill risk. He thinks this method is effective measures to prevent oil spills from offshore oil facilities.

The domestic scholar Ran Yuru, Wang Xuechang(2011) studied on the Qingdao port oil spill risk.To simulate the tide and wind, on the basis of predicting the oil spill oil film dynamic drift process in different periods . Analyzing the influence of the oil spill on the surrounding area ,so as to provide some guidance for the treatment of oil spill pollution.

Gui Ke (2011),he focused on the research of oil spill pollution may harm to marine ecosystems and humans, introduced the physical and biological methods of oil spill accident,.What is more, he putted forward comprehensive prevention suggestion of oil pollution.

Mu Lin, Zou Heping(2011) paid more attention to the numerical model of offshore oil spill, including the oil spill model, oil spill model, oil particle model and oil spill model. It provided a reference for further oil spill prediction and oil spill pollution emergency work.

Liu Tao, Liu Minyan (2012), through the analysis of ship oil spill pollution accident, concluded that the oil spill pollution have a significant impact on marine ecosystems and fisheries resources, tourism and shipping industry .Urging people to attach importance to the dangers of ship oil spill.

Zhang Qian, Liu Lin (2016) studied on the marine oil spill pollution assessment model , using fuzzy comprehensive evaluation method, in depth analysis of the study on overflow effects of oil pollution factors. In order to improve and perfect the oil spill pollution degree evaluation index system, coming up with two factors, which are the amount of oil spill and the distance from the shore. Constructing the new ocean sensitive area table and calculate the weight of each index membership degree subset. Finally, this model was applied to 2002 Bohai Suizhong 36-1 oil field oil spill accident assessment center platform and pollution assessment level caused by increasing people's attention to the Marine environment.

According to the literature, the research on the oil spill is still relatively mature and perfect. However, while studying the problem of oil spill, the main research directions are focused on the prediction and control of oil spill pollution. The lack of

awareness of oil spill pollution hazard. At the same time, there is no specific port as the research object to analysis the impact of spilled oil pollution on a specific port and nearby areas.

Therefore, this article will take Qingdao port as a specific case, to analysis the cause of oil spill accident in Qingdao port and its impact on port, in order to improve people's awareness of the harm of oil spill pollution. And providing reference for the development of other ports.

Chapter 3 Environment analysis of Qingdao port

In this paper, in order to better analyze the impact of oil spill pollution on Qingdao port, so investigated the situation of Qingdao port and the environment and resources of the surrounding sea environment. Through this investigation, Detailed grasp of the Qingdao port information, and lay the foundation for the theoretical analysis of the paper, which can put forward targeted suggestions, reducing the negative impact of oil spill on Qingdao port.

3.1 Brief introduction of Qingdao port

Qingdao port is located in the south of the Shandong Peninsula, the geographical coordinates for longitude is 120 ° 19 ', latitude is 36 ° 05 ', and close to the yellow sea, and the Korean peninsula and Japan across the sea. Qingdao port was founded in 1892, mainly engaged in container, crude oil, coal, grain and other cargo handling, storage, transit, distribution and other logistics service and international passenger service. In 2015, the throughput was 4.85 tons, and the container finished 17.44million TEUs, ranking seventh in the world.

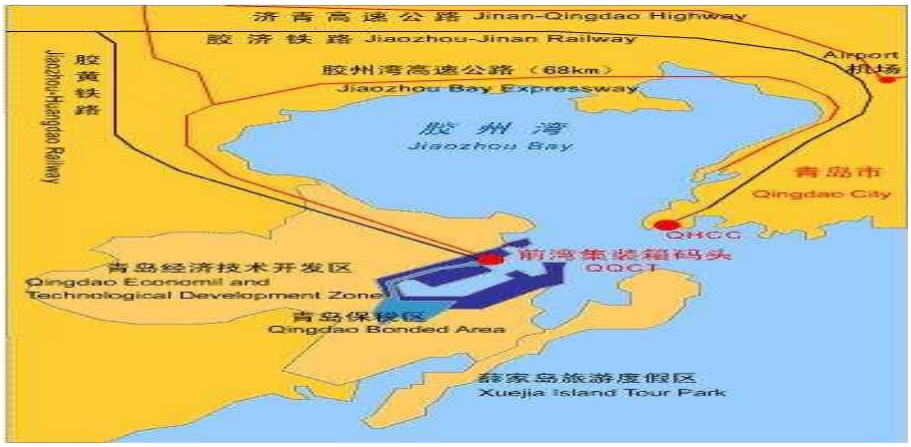

Table1-The location of Qing Dao port

Source: Baidu Wikipedia

In recent years, Qingdao port actively promoted the transformation and upgrading, and vigorously implemented the Internet strategy and internationalization strategy. Actively integrate into the national initiative "The Belt and Road" strategy, speeding up the construction of inland port. Moreover, Qingdao is a coastal city with beautiful scenery and unique natural scenery. It has abundant tourism resources and is known as "Oriental Switzerland".

3.2 Natural environment

3.21Temperature

Qingdao is located in the north temperate monsoon region, is a temperate monsoon climate. The annual average temperature is 12.1 degrees centigrade, the extreme high temperature is 35.4 degrees over the years, and the extreme minimum temperature is 16.0 centigrade over the years.

3.22 Annual precipitation

The average annual precipitation is 755.6mm; rainfall is concentrated in June to September each year, and precipitation accounts for about 70% of the total annual precipitation.

3.23 Fog condition

The average annual fog day is 46.9 days, and the sea fog is prevalent between April and July every year. The average annual fog days that visibility is less than 1km is 15.8 days. It has little effect on shipping and production.

3.24 Wind condition

Summer, mostly south wind and southeast wind, winter, mostly north wind and northwest wind. More than 7 levels of high winds for about 8 days a year; Typhoons occur about one to two times a year and have little impact on the port.

3.3 Infrastructure environment of Qingdao port

3.31 Port and throughput

The port of Qingdao is composed of Qingdao old port area, Huangdao oil port area, Qianwan new port area and Dong Jikou port area. Qingdao has 15 docks, 73 berths.

The throughput of Qingdao port is as follows. Throughput is an indicator that reflects the overall economy and import and export trade. According to the country's "11th Five-Year" plan, Qingdao port changed from the traditional port development model to diversified development, and gradually shifted from a single cargo handling function to providing modern logistics services and growth services. 2016, the annual cargo throughput exceeded 5 tons. Throughput achieved a major breakthrough, reaching 5.0036 tons, an increase of 3.3%, ranking seventh in the world, while operating performance continued to grow.

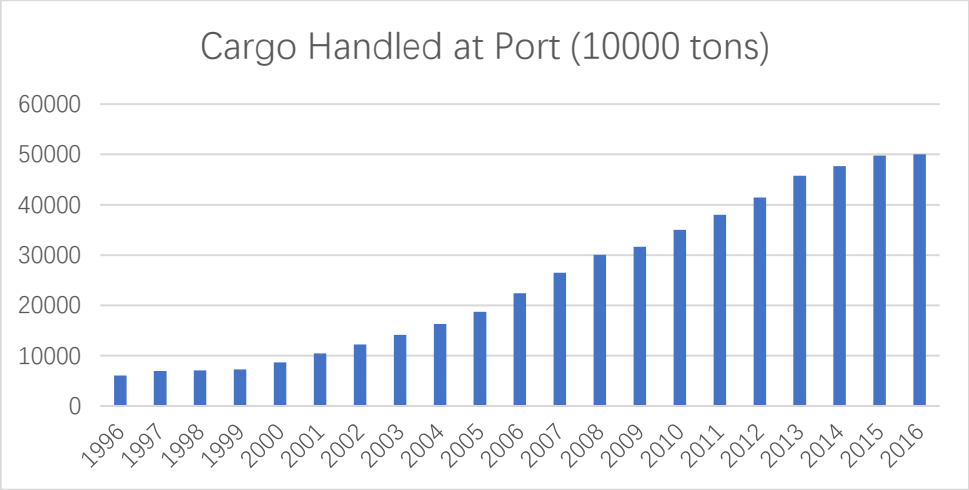

Figure1-The throughput of Qingdao port
Source: www.stats-qd.gov.cn

3.32 Channel and anchorage

The shipping lanes in and out of the Qingdao port are divided into two parts. The waterway is the channel for the inlet of Jiaozhou bay after entering the waterway of Jiaozhou bay.

The main channel of the outer sea channel is 1.8 ~ 27 nautical miles wide, which is about 45 kilometers long, which can be used in different directions and different grade ships to enter the main channel. There are 6 main wan internal waterways in Jiaozhou bay, which can be used for the entry and exit of 10,000 ton ships.

There are four main types of anchorages in Qingdao port: commercial anchorage, quarantine anchorage, temporary anchorage, and tanker anchorage. In addition, Qingdao port is planning a new anchorage, the new anchorage waters area of about 32 million square meters, can anchor more than 10000 tons large ships 30.

3.33 Loading and unloading capacity

There are 752 loading and unloading machinery in Qingdao port, and the main loading and unloading machines are at the advanced level of international ports. Among them, there are 144 cranes, such as gate machine, tire crane and floating crane. The maximum lifting capacity is 320 tons. The port of Qingdao has 10 marine loading arm for carrying oil. The efficiency of crude oil and refined oil loading and unloading equipment is 3500 cubic meters per hour , which can meet the loading and unloading needs of the oil tankers of 300 ,000 tons or more.

3.34 The current situation of oil spill emergency facilities in Qingdao port

Qingdao port is located in Jiaozhou Bay, mainly engaged in the sea transportation business of Sheng Li oil field. Chinese is the largest crude oil imports base, every year the arrival of ship has more than 100 thousand ships, maximum transportation capacity

reached 12000 m^3. According to the plan of oil spill emergency capability issued by the Qingdao municipal government, it can be seen that the Qingdao port has the ability to cope with the oil spill. The existing oil spill treatment equipment in Qingdao port is as follows;

Name of oil spill emergency equipment	Quantity
Oil Containment Boom	31600m
Oil Spill Dispersant	211.7t
Oil spill dispersing agent spraying device	138 device
oil sorbent mat	85.67 t
Oil spill cleaning device	37 device
Oil Spill Recovery Vessel	14 vessels
Auxiliary vessel	56vessels
Oil suction towline	24400 m

Table 2- The existing oil spill treatment equipment in Qingdao port

Source: Qingdao Maritime Bureau

As can be seen from the table, Qingdao port existing oil spill emergency processing equipment, especially the oil spill recovery ship, it is China's most advanced oil spill emergency recovery ship, Every hour, can recyclable oil slick 200 cubic meters . Also can collect the garbage and enteromorpha in the sea. Therefore, according to the existing oil spill treatment equipment in Qingdao port, after comprehensive analysis, it can be concluded that the current oil spill emergency equipment in Qingdao port has satisfied the emergency capacity of 2000t oil spill. But in the actual processing of oil spill accident, considering the actual weather conditions, factors such as professional operators, about 80% of the actual emergency ability is about the theoretical value, the Qingdao port has actually have the oil spill emergency processing capacity of 1500 t.

In conclusion, through the above content, We can have a good understanding of the infrastructure environment and current situation of oil spill emergency facilities in Qingdao port. It can be seen that Qingdao port has enough berths, modern loading and unloading equipment, Developed hinterland economy, wharf with enough area, perfect service facilities and advanced development strategy. These factors have contributed to the prosperity and development of Qingdao port. However, in recent years, with the rapid development of Qingdao port, the throughput is rising, therefore, in order to the development of port, it continues to build the new terminal, anchorage. The number of ships entering and leaving the port is increasing, the ship itself will have oil spill, and the port equipment also has oil spill risk. Therefore, the probability of oil pollution in Qingdao port is increasing.

Chapter 4 Statistical analysis of oil spill accident in Qingdao port

The contents of this chapter mainly discuss the classification standards of oil spill accidents in China, and judge the seriousness of oil spill accidents in Qingdao port. The oil spill data of Qingdao port from 1974 to 2014 were collected and classify the oil spill accident, to determine the cause of the accident and the harm to the port.

4.1 Spilled oil accident classification

Oil spill pollution accidents can be divided into two categories: operational oil spill and accident oil spill. Operational overflow accidents are mostly caused by human error or intentional behavior. Such as the crew don't comply with the relevant regulations, illegally discharge of bilge water, oil, waste oil, etc., or because of work error when loading and unloading oil, stagger off valve or flange joint, during fuel tank full spillover or pollution caused by the pipeline rupture, etc

The accident is mainly caused by the marine accident. For example, accidents caused by the collision, stranding, rocks and fire explosion caused the sudden oil spill caused by oil leakage.

4.2 Classification standard of oil spill

The evaluation of oil spill level is mainly based on the amount of oil spill. Generally speaking, the greater the oil spill, the greater the threat of oil spill.

In China, according to Ministry of Transport of the People's Republic of China released the grade standard of newly spilled oil accident in 2015, in addition to considering the amount of oil spill, but also consider the elements of casualties and direct economic losses and casualties, according to the oil pollution situation, to formulate rules. The new regulations divide oil spill accidents into four grades: I, II, III and IV. The new regulations divide oil spill accidents into four grades: I, II, III and IV.

Treatment of first or second grade of accidents shall be formulated by the State Oceanic Administration, according to the circumstances of the accident contingency plans, unified command, treatment III and IV grade accident plan by the local maritime department, arrange the execution plan.

Classification standard of oil spill accident grade			
Grade	Casualties	Amount of spill oil	Economic loss
Class Ⅰ	Causing more than 30 deaths or serious injuries to 100 or more persons	>1000t	>100 million yuan
Class Ⅱ	Causing 10~30 people died, or 50 ~100 people were seriously injured	500~1000t	50~100 million yuan
Class Ⅲ	Causing 3~10 people died or 10~50 people seriously injured	100~500t	10~50million yuan
Class Ⅳ	Causing 1~3 people died or1~10 people seriously injured	1~100t	1~10 million yuan

Table3- Classification standard of oil spill accident grade

Source: The official website of Ministry of Transport of the People's Republic of China

At present, oil spill accidents occur in the fourth and third grades in China every year. Once an oil spill occurs, it not only seriously pollutes the environment and coastline of the sea, increases the cost of removing oil pollution, but also causes casualties. Therefore, it is urgent to know well the harmfulness of oil spill and to prevent and control oil spill pollution.

4.3 Statistical analysis spilled oil accident

Qingdao port is located in the Jiaozhou Bay, with Sheng Li oil field nearby, mainly engaged in container, crude oil, cargo handling, storage, transit, distribution and other logistics services. In recent years, with the continuous expansion of the scale of the port, the scale of production and transportation of crude oil, refined oil and the expansion of

the Qingdao port has become a high incidence of oil spills. The following is a statistics of oil spill accident in Qingdao port from 1974 to 2014.

Number	Year	Place	Ship' name	Cause	Spilling quantity(t)
1	1974	Jiaozhou Bay	Daqing 31	On the rocks	895
2	1975	Huangdao Dock	Daqing 35	Oil spill at oil bunker	4
3	1975	Channel	Daqing 30	On the rocks	33
4	1975	Huangdao Dock	Daqing 53	collision	3
5	1975	Dagang Duck	Nanping	Operation error	20
6	1975	Anchorage	Daqing15	Oil spill at oil bunker	7
7	1975	Da Gang Duck	Daqing36	Oil spill at oil bunker	4
8	1975	Huangdao Dock	Daqing41	Oil spill at oil bunker	2
9	1976	Dagang Duck	Huangdao	Marine loading arm shedding	15
10	1977	Huangdao Dock	Daqing244	Oil spill at oil bunker	30
11	1979	Huangdao Dock	Daqing240	Operation error	10
12	1979	Channel	Cyrus	Collision	350
13	1980	Jiaozhou Bay	Daqing256	On the rocks	43
14	1983	Jiaozhou Bay	Eastern Ambassador	On the rocks	3343
15	1984	Jiaozhou Bay	Jiacui	On the rocks	757
16	1986	Huangdao Dock	Daqing245	Explode	100
17	1987	Huangdao Dock	Huhai 2	Marine loading arm fall off	120
18	1994	Anchorage	Malprabha	Collision	100
19	2001	Dagang Duck	Huhai78	Oil spill at oil bunker	3
20	2001	Huangdao Dock	Shamidun	Marine loading arm fall off	25

21	2002	Dawan oil depot	Baode1136	Operation error	1
22	2004	Huangdao Dock	Zheleyou 7	Collision	3
23	2005	Huangdao Dock	Taitan juren	Marine loading arm fall off	25
24	2006	Channel	Fuhai	Collision	64
25	2010	Dagang Duck	Hehua	Oil tank cracking	1
26	2011	Huangdao Dock	Youlan	Marine loading arm fall off	2
27	2014	Channel	Dongfang Richu	Collision	30
Total					5990

Table4- Statistics of oil spills accident in Qingdao port from 1974 to 2014

Source: Author's own collection

According to the classification of the level before the oil spill, it can be seen from the above table, the number of oil spill accident in 1-100 t had 20 cases, occupy 74% of the total number of accidents, the number of oil spill accident in 100 - 500 t had four cases, occupy 15% of the total number of accidents. The amount of oil spill accident in 500-1000t had 2 cases, the percentage of the total number of accidents accounted for 7.4%.

The oil spill in excess of more than 1, 000 tons was only one that is 1983 Feoso Ambassador of oil spill accident, which accounted for 3.6 percent of the total. From the above data, it can be concluded that the level of oil spill accidents at Qingdao port is mainly class 3 and 4. The oil spill below 100t is the main oil spill in Qingdao port.

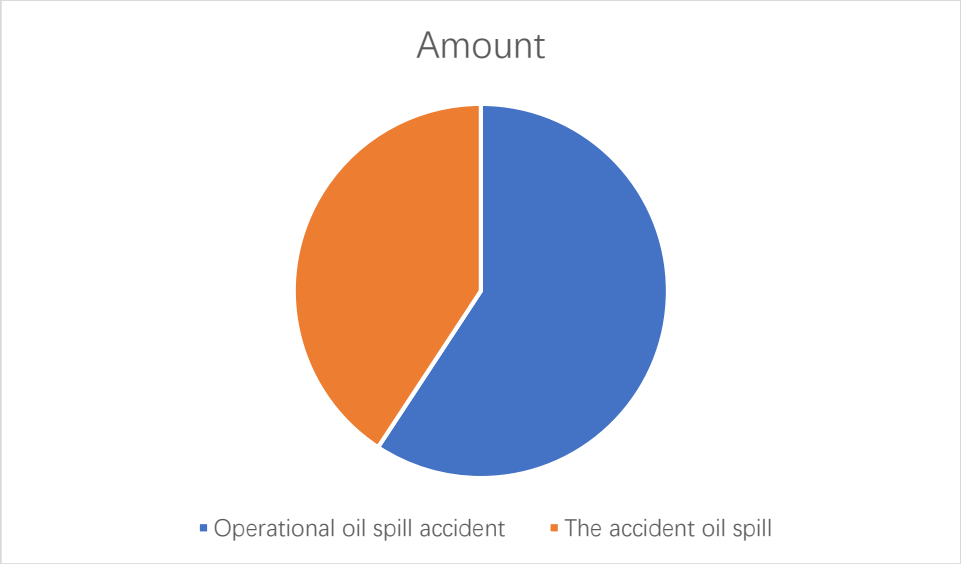

Table5- The type of spilled oil accident in Qingdao port

Source: Author's own work

According to the type of spilled oil accident, the number of operational oil spill accident is16, and the number of accident oil spill is 11. The number of accidental oil spill reached 5651 t, accounting for 94% of the total number of spilled oil, and in the event of accidental oil spill, every time the number of oil spill is bigger, to the harm of the marine ecological environment is also bigger.

According to the location of the accident, as shown in the following table, 16 oil spills occurred at the wharf, 4 cases of oil spill occurred in the channel and the reef, 2 oil spill accidents occurred in the anchorage, and 1 oil spill accidents occurred in the oil depot. Therefore, wharf is a highly risk area of oil spill in Qingdao port.

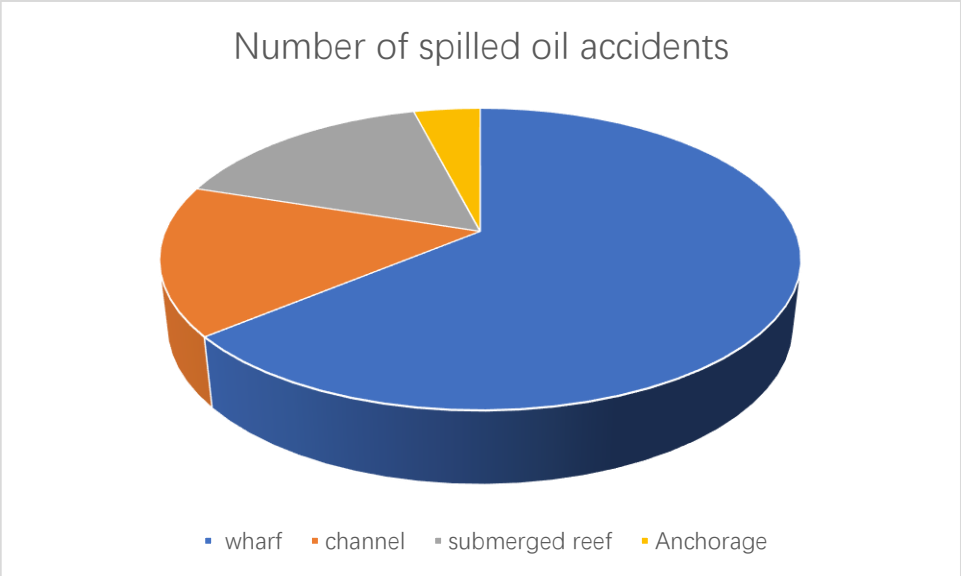

Table6-The location of the oil spill accident

Source: Author's own work

To sum up, due to its special geographical position, the wharf, channel and submerged reef become the highly risk area of oil spill in Qingdao area, and the oil spill is also concentrated in 1-100t. At present, the reef has been blown flat, the existence of navigation problems have resolved. Therefore, wharf and waterway are the areas that should be paid attention to.

The conclusion: Based on the data analysis can be seen, the Jiaozhou Bay, Huangdao dock, Dagang dock, wharf and channel is a highly risk area that happen oil spill accidents. Once the oil spill is serious, because the distance from the Qingdao port is close, oil easily polluted waters near the port, contaminated coastline. So it must analysis the oil spill accidents in these areas, to determine the cause of the accident, and put forward some prevention and control measures to the port.

Chapter5 Analysis the cause and impact of spilled oil pollution on the port

Through the contents of the fourth chapter, we can know the highly risk areas of oil spill in Qingdao port. The following will according to the location of the oil spill and the amount of oil spill, analyze the cause of oil spill and the impact of oil pollution on Qingdao port.

5.1 Analysis the cause of spilled oil

5.11 Natural factor analysis

Although Qingdao is an extremely large type of port in China, and it is also a world-famous port, its navigation condition is not ideal because of its special geographical location and coastal conditions. After the last chapter of the data analysis, it can see that the oil spill occurred mainly in the region of Jiaozhou Bay, Huangdao dock ,Dagang dock and channel, and most of the cause of oil spill accidents because of ship collision, stranding and due to improper operation and other factors. Therefore, the causes of oil spill can mainly be divided into natural factor, human factor and ship factor.

From natural factor, under normal circumstances, the wider the channel, the less obstacles, the less prone to oil spills. Through the previous data analysis, it can see that the Jiaozhou Bay and channel are the high incidence areas of oil spill. This is because the navigation conditions in these two areas is not optimistic, the specific performance in the following aspects: first, the Jiaozhou bay mouth narrow, only the narrowest 2.1km, ship navigation under the condition of high density is likely to cause a collision. The water depth in Qingdao port is not enough, the channel is narrow, the surrounding terrain is more complex, easy to cause the ship ran aground and ran aground. Moreover, the outer and outer areas of Qingdao are complicated and the reefs are more difficult to

avoid, so it is easy to cause oil spill accidents, causing oil pollution to pollute the sea surface and surrounding areas.

With the development of Qingdao's economy, the Shandong provincial Maritime Bureau has increased investment in Qingdao port every year. Qingdao port 's construction scale and construction speed have increased unprecedentedly. The volume and frequency of freight ships in Qingdao port are increasing, the ships are becoming larger and larger, and the piers are crowded. The throughput has increased year by year, and many large oil terminals are under construction, and the enlargement of the port area and the increase of the branch of waterway which made the channel from not wide to narrower. Moreover, the increasing number of small ships and illegal operating vessels are also occupying the waterways. These factors make the navigation of ships become more and more difficult, and increase the risk of oil spill.

5.12 Human factor analysis

Human factors are also an important factor in the oil spill in Qingdao port. The human factors mainly refer to ability of the crew and the of port 's staff and wharf 's staff to cope with the emergency. In the oil spill in Qingdao port, a part of the oil spill pollution was caused by staff errors. With the rapid development of the port of Qingdao, the demand for human resources is also rising, but for the port staffs, there is not enough professional training to deal with oil pollution, especially in the emergency, so when the oil spill accidents happen, it is difficult to cope with, even aggravating oil pollution.

At sea, it is always facing changeable weather conditions and complicated navigation conditions. These factors are a big challenge for ship navigation. It can be said that the crew's comprehensive quality, professional technical level and the emergency response capability, and related to the channel in familiarity directly determines whether the oil spill occurred, and the severity of the accident. Generally speaking, after the formal training of the crew, their skill levels are relatively high, familiar with the port and dock near the marine environment, and can judge and timely

disposal of some unexpected accidents, so as to avoid collision, stranding some rocks, reduce the rate of oil spill pollution.

However, with the development of the shipping industry, the professional level of the crew is different. The narrow channel of Qingdao harbor also tests the skill level of the crew. If the navigation crew are not familiar with the situation of Qingdao port, occurrence of operational errors, will lead to oil spill accident occur, when face of this emergency, the crew often excessive tension, lack of judgment, it is difficult to make emergency treatment, increase the severity of oil spill accidents.

5.13 Ship factor analysis

The number of vessels in Qingdao port are numerous and complex, including cargo ships, oil tankers, liquefied gas carriers, bulk chemical boats, container ships and other cargo ships. In recent years, Qingdao port has seen a trend of large-scale ships, with a large proportion of oil tankers above 50000t. Once a large ship collides, it is possible to cause a large amount of oil spill, contaminating the sea surface and port. In addition, large container ships and bulk carriers are not oil tanker, but also carry a large amount of fuel oil. If an oil spill occurs, it can cause a large amount of oil pollution.

5.2 Analysis the impact of oil pollution on the Qingdao port

5.21 The impact on the port

On the one hand, after the oil pollution occurs, it will not only pollute the marine environment and the ecological environment, but also have a negative impact on the port. First, the berthing area of the Qingdao port pier is very sensitive to oil spills. In general, the occurrence of oil pollution on the wharf, need to clean up the waters, to a certain extent will affect the ship out of Qingdao port, thus affecting the port's

production efficiency. It is also very difficult to clean the polluted sea areas, and the cost of cleaning is also higher. Oil pollution compensation and port expenditures as below, Qingdao port annual oil pollution compensation are increasing, accounting for almost 9% - 10% of the port expenditure. It indicated the harm of oil pollution on port is increasing year by year.

Year	Oil pollution compensation (10000 yuan)	Port expenditure (10000 yuan)
2011	700	7200
2012	780	8105
2013	907	8506
2014	943	11811
2015	1124	11570

Table7-Oil pollution compensation and port expenditures

Source: Qingdao Maritime Bureau

5.22 Impact on fisheries resources

On the one hand, Qingdao port is located in the Jiaozhou Bay, Jiaozhou Bay is a highly risk area of oil pollution accident. Qingdao City, the coastline length of 782.7 km, 162 km coastline of Jiaozhou Bay. Jiaozhou Bay is rich in marine fisheries resources, breeding of shellfish, abalone and other rare aquatic resources, coastal tidal flats of farmed fish and shrimp, etc., once the Jiaozhou Bay oil pollution occurs, will cause severe economic losses.

The damage caused by oil spill pollution to the marine environment and fishery is manifold. On the one hand is the harm to adult fish. Because fish of petroleum hydrocarbon enrichment, makes the catch of fish oil smells, lower the quality of its products, make its sales price significantly lower than the market price, affect the economic income. And in the event of oil spill, a large number of crude oil that can be massive, under the influence of tide and wind, drift, if floating oil into the fishery area,

will contaminate local sea waters, affect the quality of fishing varieties. In severe cases, it will cause massive death of fish, lead to devastating damage to coastal beaches and shallow marine aquaculture. And the drift of crude oil, which will be difficult to recover in a period of time, will affect coastal fishermen's normal operations.

On the other hand, it is the harm to young fish and fish eggs. The early stage of life development of fish is more sensitive to the pollutants in the stages of the whole life cycle. During the spawning period, the oil pollution will result in the decrease of fish eggs and high mortality, resulting in the decrease of fishery resources. Experts from the Chinese academy of fishery sciences have shown that the loss rate of fishery resources caused by oil spill is about 50%- 60%.

To sum up, oil spill pollution will not only lead to the reduction and death of fish, but also lead to serious economic losses. It will also damage the marine environment and damage the balance and diversity of marine ecological environment.

5.23 Influence on tourism

In recent years, the tourism situation is as follows. It can see that the total number of tourists is increasing, and the proportion of tourism industry in Qingdao is increasing, which brings about the increase of tourism revenue. There are many tourist resources near the Qingdao port, and many tourist attractions have been developed along the coast near the port. Through the analysis of the past, it knows that the Huangdao duck, Dagang duck is a high incidence area of oil spill, the pier has a large number of ships in and out every day, various operation activities and easy to cause oil spill pollution accidents. Once the oil spill occurs in the port and vicinity, it will have a serious impact on the nearby tourist attraction. JC Cirer-Costa believe that an oil spill which released only a very small volume of pollutants into the sea, but which, nonetheless, had a totally disproportionate impact on the economy of the local tourism sector. So the influence of oil pollution on the tourism industry is as follows.

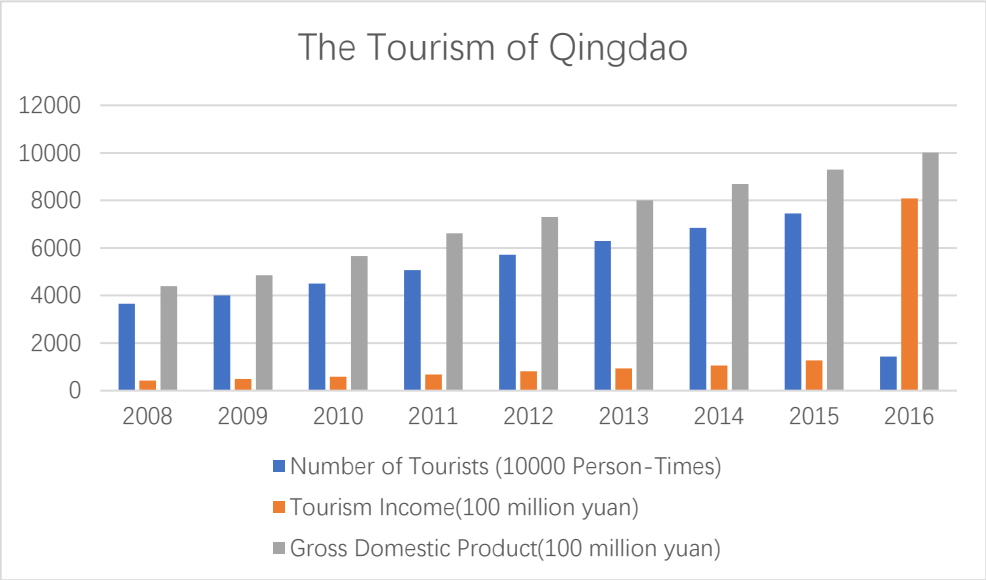

Figure2-The tourism of Qingdao

Source: www.stats-qd.gov.cn

Name	Distance to port (km)
1 Jiaozhou Bay fishery area	13
2 Hondao fishery area	11.9
3 Xue Jiadao tourism resort	4.8
4 Shi Laoren tourism resort	12
5 Sha Zikou aquaculture area	18
6 Tuandao-Shilaoren tourist coastline	3.5

Table8-Distance from Qingdao port to the tourist attraction

Source: Author's own collection

(1) Polluted seawater

Sea water is the core element of seashore tourism landscape, the quality of sea water is destroyed, and the value of tourism landscape will be seriously affected. Oil spill is an important cause of damages to marine resources, when spilled oil flows into the sea, it will spread rapidly. An oil film is formed on the sea surface to isolate the exchange of water from the atmosphere and disrupt the normal re oxygenation

conditions, thereby reducing the amount of oxygen entering the sea water and thereby reducing the self purification capacity of the sea. The occurrence of oil spill or drift into the sea area will reduce the ornamental value of the sea water and destroy the swimming function of the bathing beach. Because of the pollution of oil spill and the decline of water purification capacity, it will take a long time to restore the original status of the sea water in the tourist attractions, which will have a long-term negative impact on tourism.

(2) The damage of marine organism

Living resources in the seaside tourist attractions are important ornamental landscapes, mainly including plankton, swimming animals and benthos in the sea, as well as various animals and plants along the coastal land. When oil spills into the sea, photochemical reactions will take place in a few hours, producing oxides of acids and sulfur, which can be very harmful to marine life. Oil spill pollution can destroy the living environment and food sources of organisms, and then affect the living conditions of organisms and cause damage. The biological damage inevitably affects the landscape value and food value of the biological resources of scenic spots, and brings about losses to the tourism industry.

(3) The damage of beach and reef damage

The beach and the reef are the basic landscape elements of the seaside scenic spot, and the beach and the sea together form a natural bathing beach. After the oil spill accident, under the action of wind and waves, the oil or the mixture of oil and water rushed to shore, after the sun and the wave function, wrapped sand to form small particles, irregular distribution in the sand and rocks. Causing serious pollution, damage to the beach and reef ornamental value. As a natural bathing beach, the recreational function of the beach is also damaged, resulting in the decrease of tourists and the loss of tourism.

(4) The damage of facilities

When oil spills into the tourist attractions, the cruise, yacht, sailing boat, surfing board and other marine recreational facilities which are moored or moved on the sea surface will be difficult to avoid being polluted and suffer economic losses. If the sea fishing base and diving base suffered from the oil spill pollution, it will have to close down. Therefore, to bear the economic losses caused by the closure, if the closure of the service contract in violation of the prior agreement, but also bear the corresponding damages

(5) Economic loss of tourist attraction

Ticket revenue is an important guarantee for the normal operation of seaside tourist attractions, and also an important source of revenue for local governments. In the case of oil pollution threat and destruction, it will affect the visitor's plan to visit the scenic spots and reduce the number of tourists in the scenic spots. If the pollution is serious, scenic spots may be closed for some time in the future, so there will be no tourists entering the scenic spots. Because of the decrease in tourist numbers or lack of tourists, there is a decrease in ticket receipts or no ticket receipts, which brings serious economic losses to scenic spots and local governments

Conclusion: the pollution of oil spill is harmful to the port, which will not only increase the cost of cleaning up the port, but also reduce the daily income. It will also bring negative impact on the tourism and aquaculture industry near the port. Therefore, it is urgent to prevent and control oil spill pollution

Chapter 6 Regression analysis of oil pollution

Through the elaboration of the fifth chapter, we can know the cause of oil spill in Qingdao port and the influence of oil pollution on the port. But fifth chapter mainly discusses the theory of oil pollution on Qingdao harbor hazards, in order to better quantify the port 's economic losses caused by oil pollution, it will be through the establishment of a multiple regression model, to determine the mainly port 's economic losses reflect in what aspects.

6.1 Multiple linear regression analysis

Regression analysis is a mathematical method of statistical analysis, used to study the relationship between one variable, another variable, or multiple variables. In regression analysis, if there is only one independent variable and one dependent variable, and the relation between the two can be approximated by a straight line, the regression analysis is called unitary linear regression analysis. If the regression analysis contains two or more independent variables, and there is a linear relationship between the two variables, it is called multivariate linear regression analysis

6.11 Multiple linear regression model

When faced with a situation of development and change depends on several factors mutual influence, and it is difficult to distinguish between the factors affecting the importance, or some factors on the dog, but also cannot ignore its effect, then carries on the regression analysis using monadic linear regression method, the result is not accurate, so you need to use multiple regression analysis. Multiple regression, by means of two or more than two variables and a correlation analysis of variables, where Y represents the explained variable (the dependent variable), X represents the explanatory

variables (independent variables), with the X_1, X_2, X_3, etc. The multiple regression analysis model is designed to better observe the influence degree of each explanatory variable on the explanatory variables and improve the accuracy of the regression effect.

Assume that a dependent variable Y is governed by P arguments X_1, X_2,... The effect of X_p and random factor epsilon, then, is that the model of multiple linear regression is:

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p + \varepsilon \quad \cdots\cdots (1)$$

Where Y is the explained variable, X is the explanatory variable, β_0 ,$\beta_1 \ldots \beta_p$ is the regression parameter, β_0 is the constant term, $\beta_1 \ldots \beta_p$ It's the regression coefficient, β_1 means when X_2, $X_3 \ldots X_p$ is fixed,... When X_1 increases one unit, and the resulting change in the regression equation, the partial regression coefficient ofβ_1 to y, Similarly, β_2 represents when x_1, x_3... X_P is fixed, When X_2 increases one unit, and the resulting change in the regression equation, εis a random error that cannot be measured.

$$E(y) = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p \quad \cdots\cdots (2)$$

is theoretical regression equation.

For a practical problem, to establish a multivariate regression equation, the first process it to estimate the unknown parameter β_0 ,$\beta_1 \ldots \beta_p$. However, in the actual study, we can not understand the characteristics of the above general model and can only estimate the general characteristics through the sample characteristics. Assuming that n independent observations are carried out, the sample data of n group is obtained

$(X_{i1}, X_{i2}, \ldots X_{ip}; Y_i), (i=1,2,3 \ldots n)$,

$$\begin{cases} y_1 = \beta_0 + \beta_1 x_{11} + \beta_2 x_{12} + \cdots + \beta_p x_{1p} + \varepsilon_1 \\ y_2 = \beta_0 + \beta_1 x_{21} + \beta_2 x_{22} + \cdots + \beta_p x_{2p} + \varepsilon_2 \\ \cdots\cdots \\ y_n = \beta_0 + \beta_1 x_{n1} + \beta_2 x_{n2} + \cdots + \beta_p x_{np} + \varepsilon_n \end{cases} \quad \cdots\cdots (3)$$

The expected value of the random error εis 0, and the variance sigma 2 is the same; And epsilon ε_1, $\varepsilon_2 \ldots \varepsilon_n$ is independent of each other and is subject to $N(0, \sigma^2)$,so the above expression can be represented as matrix $Y=X\beta+\varepsilon$ ·····(4)

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix}_{(n\times 1)} = \begin{bmatrix} X_{11}\cdots X_{1j}\cdots X_{1k} \\ X_{21}\cdots X_{2j}\cdots X_{2k} \\ \cdots \quad \cdots \quad \cdots \\ X_{n1}\cdots X_{nj}\cdots X_{nk} \end{bmatrix}_{(n\times k)} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_k \end{bmatrix}_{(k\times 1)} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}_{(n\times 1)}$$

6.12 Least square method of parameters

The parameter estimation of multiple regression model is the same as linear regression equation, which requires the sum of squared error.

The least square method is used to estimate the parameters. So using $\beta=(\beta_0, \beta_1, \ldots\beta_P)^T$ to makes the error squared reach minimum. The calculation formula is as follows.

$$\begin{aligned} Q(\beta) &\triangleq \sum_{i=1}^{n} \varepsilon_i^{\,2} = \vec{\varepsilon}^{\,T}\vec{\varepsilon} = (Y - X\beta)^T (Y - X\beta) \\ &= \sum_{i=1}^{n} (y_i - \beta_0 - \beta_1 x_{i1} - \beta_2 x_{i2} - \cdots - \beta_p x_{ip})^2 \end{aligned} \quad \cdots\cdots\cdots\cdots (5)$$

Since $Q(\beta)$ is a non-negative quadratic function of $\beta_0, \beta_1, \cdots, \beta_p$, there must be a minimum value. By using calculus to compute extreme values, the following results are obtained

$$\begin{cases} \dfrac{\partial Q(\hat{\beta})}{\partial \beta_0} = -2\sum_{i=1}^{n} (y_i - \hat{\beta}_0 - \hat{\beta}_1 x_{i1} - \hat{\beta}_2 x_{i2} - \cdots - \hat{\beta}_p x_{ip}) = 0 \\ \dfrac{\partial Q(\hat{\beta})}{\partial \beta_1} = -2\sum_{i=1}^{n} (y_i - \hat{\beta}_0 - \hat{\beta}_1 x_{i1} - \hat{\beta}_2 x_{i2} - \cdots - \hat{\beta}_p x_{ip}) x_{i1} = 0 \\ \dfrac{\partial Q(\hat{\beta})}{\partial \beta_k} = -2\sum_{i=1}^{n} (y_i - \hat{\beta}_0 - \hat{\beta}_1 x_{i1} - \hat{\beta}_2 x_{i2} - \cdots - \hat{\beta}_p x_{ip}) x_{ik} = 0 \\ \dfrac{\partial Q(\hat{\beta})}{\partial \beta_p} = -2\sum_{i=1}^{n} (y_i - \hat{\beta}_0 - \hat{\beta}_1 x_{i1} - \hat{\beta}_2 x_{i2} - \cdots - \hat{\beta}_p x_{ip}) x_{ip} = 0 \end{cases} \quad \cdots\cdots\cdots\cdots (6)$$

For the $Q(\beta)$ to get the hypothesis partial derivative, can obtain the normal equations system $X^T X\hat{\beta} = X^T Y$,according to the hypothesis $R(X) = p+1$, can get

this equation $R(X^TX)=R(X)=p+1$,so there exists $(X^TX)^{-1}$, so solving normal equations system, can get $\hat{\beta}=(X^TX)^{-1}X^TY$ ……(7)

Therefore, the sample regression equation is:

$\hat{y}=\hat{\beta}_0+\hat{\beta}_1x_1+\hat{\beta}_2x_2+\cdots+\hat{\beta}_px_p$ …… (8)

6.13 Estimation of error variance σ^2

Bring each observation variable value into the regression equation, then can get the estimation of the dependent variable values (as fitted values). Formula is as follows

$\hat{Y}=(\hat{y}_1,\hat{y}_2,\cdots,\hat{y}_p)^2=X\hat{\beta}$ …… (9)

Vector $\vec{e}=Y-\hat{Y}=Y-X\hat{\beta}=[I_n-X(X^TX)^{-1}X^T]Y=(I_n-H)Y$ is called residual vector ， and $H=X(X^TX)^{-1}X^T$ is called N order symmetric idempotent matrices.

$\vec{e}^T\vec{e}=Y^T(I_n-H)Y=Y^TY-\hat{\beta}^TX^TY$ is called square sum of residue（SSE）. Due to $E(Y)=X\beta$, $(I_n-H)X=0$ ， so $E(\vec{e}^T\vec{e})=E\{tr[\vec{\varepsilon}^T(I_n-H)\vec{\varepsilon}]\}=tr[(I_n-H)E(\vec{\varepsilon}\vec{\varepsilon}^T)]$

$=\sigma^2tr[I_n-X(X^TX)^{-1}X^T]=\sigma^2\{n-tr[(X^TX)^{-1}X^TX]\}=\sigma^2(n-p-1)$ ……(10)

6.14 Test of multivariate linear regression model

In the multivariate linear regression model, the necessary tests must be carried out after using the least squares method to obtain the estimated parameters. The mainly tests are the goodness of fit, the F test and the T test. To decision models whether can be applied in theory and practice.

(1) Test of goodness of fit R^2

The goodness of fit test is to test the fitting degree of the regression equation to the sample observations, that is, to test the correlation between all explanatory variables and the explanatory variables. The larger the R^2 , the better the regression equation is, and the stronger the fit of the sample data points, the stronger the relationship between the dependent variable and the dependent variable. The formula is as follows

$$R^2 = \frac{\sum(\hat{y} - \bar{y})^2}{\sum(y - \bar{y})^2} = 1 - \frac{\sum(y - \hat{y})^2}{\sum(y - \bar{y})^2} \quad (0 \leq R^2 \leq 1) \quad \cdots\cdots (11)$$

And

$$\sum(y - \hat{y})^2 = \sum y^2 - (b_0 \sum y + b_1 \sum x_1 y + b_2 \sum x_2 y + \cdots + b_k \sum x_k y) \cdots\cdots (12)$$

$$\sum(y - \bar{y})^2 = \sum y^2 - \frac{1}{n}(\sum y)^2 \cdots\cdots (13)$$

The closer the R^2 is to 1, the better the fit of the regression equation. However, the size of R^2 is affected by the number of independent variables. Therefore, it is not the only indicator to test the results of the regression model

(1) F Test

The significance test of equation is referred to as F test, which is an inference of whether the linear relationship between explanatory variables and interpreted variables in the model is significant in general. The test was explained the linear relationship between the variables of Y and all of the explanatory variables X is significant. The test is carried out on the basis of variance analysis and F test. First of all, the original hypothesis H_0 and alternative hypothesis H_1 are proposed.

H_0: $\beta_0 = \beta_1 \cdots = \beta_k = 0$; H_1 : At least one β_j is not 0， Then the formula for F is

$$F = \frac{\sum(\hat{y} - \bar{y})^2 / k}{\sum(y - \hat{y})^2 / n - k - 1} \cdots\cdots (14)$$

According to the given significant level **∂**, the degree of freedom (k, n-k-1), Find the F distribution table, obtained the corresponding critical value Fa, if F > Fa, the regression equation has significant meaning, and the regression effect is significant., if F < Fa the regression equation is not significant and the regression effect is not significant.

(2) T Test

The overall linear relationship (the significance test of the equation) can only show that the effect of all explanatory variables on the Y is significant, but it does not indicate that the influence of each explanatory variable is significant. Therefore, t-test is used to test whether each explanatory variable is significant, and the non-trivial explanatory variable is deleted by t-test. First , calculated the statistics t_j in the process of inspection. Then according to the significance level and then according to the significant level a, check the t distribution table, if | t | α > t / 2 (n - k - 1), refused to H_0, showed the explained variable to be explained variable Y has a significant effect. Computation formula is as follows:

$H_0:\beta_i = 0 \qquad H_1 :\beta_i \neq 0$,i=0，1,2⋯k

$$t_j = \frac{\hat{\beta}_j}{\sqrt{S_{\hat{\beta}_j}^{\ 2}}} \sim t(n-k-1) \qquad \cdots\cdots (15)$$

6.2 Establishment of model

In the petroleum transportation business, Qingdao port is mainly engaged in the transportation of Sheng Li oil field. With the expansion of Qingdao port transportation scale and the increase of demand, the risk of oil spill accidents is also increasing. Therefore, this paper will establish a multiple regression model, to quantify the economic losses caused by oil spill on the port.

The pollution caused by oil spill is various, which not only pollutes the environment of the port, but also affects the daily operation of the port. The harm of oil spill to port is mainly caused by serious economic loss to port, such as the increase of cleaning costs, the increase of waiting time, the opportunity cost and so on. In the oil spill, there are many factors affecting the port economic loss, such as the number of oil spills, the area of oil spill, the extent of pollution, and the extent of oil pollution after the event. The analysis found that the amount of oil, the extent of the polluted coastline,

the duration of oil spill, which are the main factor that causes the economic loss of the port.

(1) The amount of spilled oil

The amount of spilled oil is an important indicator for the assessment of oil spill pollution, and the amount of the overflow directly determines the harmfulness of the accident. When the oil spill occurs, the oil penetrates into the water, and the oil film spreads rapidly to the surrounding sea, and the amount of the overflow determines the time of the expansion process. When the amount of oil is high, the expansion of the oil film will last for about 10 hours, and when the diffusion process is over, it will start to drift under the action of wind currents. These factors have contributed to the spill's pollution and the port has been pouring more money into the clean up.

(2) Length of polluted coastline

The coastline is the boundary between land and sea, and a good coastline is a necessary condition for the development of a port. China's coastline is mainly divided into coral reef coast and mangrove coast. Qingdao is a famous coastal city and a scenic tourist city. Qingdao has a coastline of 782.7 kilometers and a number of scenic spots have been developed near the coastline. Once the coastline is polluted by oil spill, it will not only affect the daily operation of the port, but also the influence revenue of tourism.

(3) Oil spill diffusion time

Oil spill diffusion time is also an important factor in the economic loss of the port. After the oil spill accident, the oil film will first float on the surface of the sea, spread through the expansion movement, then drift and weathering, and continuously pollute the sea environment. Therefore, through multiple regression analysis, the above three factors are used as independent variables to study the effects of these variables on economic loss (Y).

The data of this paper are mainly from the statistical yearbook of Qingdao Statistical Bureau, Qingdao maritime bureau and Shandong maritime bureau. The data in this paper are the data of oil spill accidents occurring in Qingdao during the period from 1974 to 2016.

Because of the variable Y (economic loss amount) the time span of 32 years, taking into account the time value of money and the rate of inflation, so decided to discount the currency. The amount of economic loss was used as explanatory variable (Y), The amount of spilled oil is x_1, length of polluted coastline is x_2, oil spill diffusion time is x_3,. And x_1, x_2 and x_3 are explanatory variable, and multiple regression model can establish. Among them, the unit ofx_1 is t, the unit of x_2 is km, and the unit ofx_3 is h, and the unit of Y is millions. Model expression are as follows :

$$y = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \varepsilon \quad (i=1,2,3) \cdots\cdots (16)$$

Taking data into EXCEL, using regression analysis, the results are as follows

SUMMARY OUTPUT								
回归统计								
Multiple R	0.976412							
R Square	0.953381							
Adjusted R	0.9473							
标准误差	86.27406							
观测值	27							
方差分析								
	df	SS	MS	F	ignificance F			
回归分析	3	3500993	1166998	156.7868	1.89E-15			
残差	23	171193.9	7443.213					
总计	26	3672187						
	Coefficients	标准误差	t Stat	P-value	Lower 95%	Upper 95%	下限 95.0%	上限 95.0%
Intercept	77.98656	27.48748	2.837166	0.009336	21.12437	134.8487	21.12437	134.8487
X Variable	0.208843	0.060874	3.430725	0.002282	0.082915	0.334771	0.082915	0.334771
X Variable	3.585762	0.968578	3.70209	0.001175	1.582106	5.589418	1.582106	5.589418
X Variable	15.3691	3.999227	3.843018	0.00083	7.09607	23.64213	7.09607	23.64213

Table9-Multiple linear regression result

Source: The author's own calculation

Therefore, the linear regression equation is ：

$$Y=0.2X_1+3.6X_2+15.4X_3+78 \cdots\cdots (17)$$

6.3 Model test

6.31 Economic significance test

The results show that the economic losses caused by oil spill pollution are linear with the amount of spilled oil, the length of polluted coastline and oil spill diffusion time.

When the length of polluted coastline and oil spill diffusion time unchanged ,if the amount of oil spill increase 1t ,then economic losses will increase 200 thousand, similarly, if other variable not change, when the length of polluted coastline for each additional 1km, the economic loss will increase 3.6 million. If other variable not change, when oil spill diffusion time increases by one unit, the economic loss will be increased by 15.4 million.

6.32 F Test and T test

F Test

As can be seen from the results in the table， goodness of fit R^2 =0.95, This indicates that the model has a good fitting degree for the sample.

When the P- value is less than 0.05 well, then reject the null hypothesis. That means the regression coefficient is significant. In this regression model, the P -values of the coefficients of each regression are less than 0.05, so the regression coefficients are significant.

In the multiple regression model, according to a given level of significance ∂= 0.05, In the F distribution table ,when the degrees of freedom is K -1 =3 and the critical value of n - K = 23, the critical values Tα/2（23）=2.06, by regression analysis, obtained F = 156 > 3.03, so it should reject the null hypothesis H_0, and this result shows that the regression equation is remarkable.

T Test

According to the given significant levelα=0.05, by T distribution table is found ,when degrees of freedom : n-k=23, critical value Tα/2（23）=2.06. From the regression results showed that the corresponding T statistics were 3.4, 3.7,3.8, the absolute values of the three variables were greater than 2.069, indicating that both shall refuse to H0. That is to say, when other variables remain unchanged, the explanatory variable "the amount of spilled oil X_1" " the length of polluted coastline X_2 ""oil spill diffusion time X_3" respectively on the explanatory variables " have a significant impact to the amount of loss of Y

6.4 Regression result analysis

Through the analysis of the above regression results, it can be concluded that the amount of spilled oil X_1" " the length of polluted coastline X_2 ""oil spill diffusion time X_3" respectively on the explanatory variables " have a significant impact on the explanatory variables "loss amount Y". So the linear regression equation is as follows ; .

$$Y=0.2X_1+3.6X_2+15.4X_3+78 \cdots\cdots (18)$$

According to the linear regression equation, I will propose six hypotheses to see which explanatory variable has a greater influence on Y.

(1) X_1 is big， X_2 is small， X_3 is small
(2) X_1 is big， X_2 is big， X_3 is small
(3) X_1 is big， X_2 is small， X_3 is big
(4) X_1 is small，X_2 is small, X_3 is big
(5) X_1 is small，X_2 is big， X_3 is small
(6) X_1 is small，X_2 is big， X_3 is big

Because Feoso Ambassador is the most serious of the oil spill accident that happened in Qingdao port. And the amount of oil spill is 3343t, so reference this history of Qingdao, the numerical range of X_1 is from 1 to13343. Considering the

length of the coastline of Qingdao 782.7 kilometers, so the numerical range of X_2 is (10,782.7), The range of X_3 is (1,48).

For the first hypothesis, when X_1=3343, X_2=10, X_3=1, bring the numbers into the regression equation, the following results are obtained

Y=0.2*3343+3.6*10+15.4*1+78=798

For the second hypothesis, when X_1=3343, X_2=782.7, X_3=1, bring the numbers into the regression equation, the following results are obtained

Y=0.2*3343+3.6*782.7+15.4*1+78=3579.72

For the third hypothesis, when X_1=3343, X_2=10, X_3=48, bring the numbers into the regression equation, the following results are obtained

Y=0.2*3343+3.6*10+15.4*48+78=1521.8

For the fourth hypothesis, when X_1=1, X_2=10, X_3=48, bring the numbers into the regression equation, the following results are obtained

Y=0.2*1+3.6*10+15.4*48+78=853.4

For the fifth hypothesis, when X_1=1, X_2=782.7, X_3=1, bring the numbers into the regression equation, the following results are obtained

Y=0.2*1+3.6*782.7+15.4*1+78=2911.32

For the sixth hypothesis, when X_1=1, X_2=782.7, X_3=48, bring the numbers into the regression equation, the following results are obtained

Y=0.2*1+3.6*782.7+15.4*48+78=3635.12

From the above data, it can be concluded that the Qingdao port's economic losses caused by oil spill accident are mainly reflected in the pollution of coastline. And the more oil spill, the longer the duration, but also need to invest a lot of money to clean up, and seriously even closed the port, affecting the daily operation of the port and ship access.

In conclusion, through the establishment of regression model, can understand that the harm of oil pollution on the port. On the one hand, pollute of coastline and sea areas where near the port, it requires a lot of personnel and supplies to clean up the oil and increase oil spill clean-up costs. On the other hand, serious oil spill pollution will affect the daily operation of port and ships entry and departure the port, even closed port to clean up the oil, lead to the loss of the port profit. In addition, Qingdao is a famous

tourist city, tourism revenue is pillar industries, there are many seaside scenic spots near the Jiaozhou bay. Once oil spill move to the area near the scenic area, will affect the daily opening, reduce the number of visitors, which will reduce the income of tourism industry .

Chapter 7 Suggestion and Conclusion

According to the previous regression results, it can be learned that after the oil spill pollution occurred, the mainly aspect to caused port economic losses was the pollution of the coastline. Therefore, should point at the different types of coastline, put forward the measures to reduce the damage that caused by oil spill pollution. What is more, in a highly risk area where often have oil spill accidents, such as wharf, waterway area, will also put forward corresponding suggestions to reduce the amount of oil spill accidents, and reduce the negative effects of oil pollution on the port of Qingdao, to promote the prosperity and development of Qingdao port.

7.1 Shoreline conditions

The coastal zone is a land sea ecotone, which has a fragile ecological environment. Once it is polluted, it will not only be difficult to clean up, but also bring potential harm. It will be difficult to completely remove in the short term. Qingdao has a vast coastline and abundant coastal resources. Qingdao City, 782.7 km long coastline, north of South Xiang Qian Jin Kou Cun (latitude 36 degrees 36 minutes east longitude 120 degrees 46 '17, 03), South to Hongshiya town of Zhanggezhuang village. There are three coastal types in Qingdao: bedrock shoreline, silt shoreline and sandy shoreline. Among them, the Bedrock Coast is mainly composed of relatively hard bedrock, accounting for 60% of the length of the coast of Qingdao, the coastline twists and turns, in Qingdao, Laoshan and Zhushan coastal areas.

7.2 Suggestion

7.21 For different type of coastline

In view of the scheme of oil spill pollution in Qingdao coastline, should take into account the sensitivity index of coastal oil, the type of oil spill and other factors, and formulate efficient and reasonable countermeasures. Nansingh, Jurawan, according to the coastal topography and biological species and other factors, was put forward the sensitivity index of different types of coastal zones to oil spill The sensitivity index ranges from 1 to 10. The greater the number, the more sensitive the oil spill is, the priority area should be protected after the oil spill. The coastal types of Qingdao port mainly include bedrock coastline, silt shoreline and sandy coastline. Their sensitivity index was 9,6,7. Therefore, attention should be paid to the protection of these coastlines after the oil spill.

The bedrock coastline is the most vulnerable coastal type, which should be protected preferentially after the oil spill. Considering that oil spills into this kind of coast, it is difficult to drift away a lot of oil spills, which will increase pollution and control difficulties. Therefore, after the oil spill occurs, first of all, oil absorption materials should be rapidly laid down to reduce oil infiltration into the subsoil, converting the spilled oil into solid waste, and then further centralized treatment. Use physical and chemical treatment, spray dispersant, decorate oil fence, recover oil spill, prevent oil spill into the coast. If the oil spill enters the coast, treatment should be set for specific conditions. If the spilled oil floats on the sea, a physical method should be adopted to enclose it with an oil fence to prevent it from spreading at sea, and then use an oil skimmer to recycle the oil. If the spilled oil has penetrated into the soil layer of the ground, oil absorption material should be placed so that the spilled oil is glued to its surface so that it can be absorbed and recovered.

It is also recommended that bioremediation be used to clean up oil pollution. Bioremediation is a new method of oil spill treatment, usually using some marine microorganisms, they have the ability to oxidize the decomposition of oil, which can

effectively remove oil spills at sea. But method of bioremediation can not cause secondary pollution, and other additives can accelerate the degradation of natural biological combination, compared with chemical and physical methods, effect of bioremediation on people and the environment caused by the small, and the repair cost is only 35% of the traditional physical and chemical remediation. The coastline of silt and sandy shoreline are sensitive to the pollution of oil spill, which is closely related to the action of tidal wave. The general oil spill can be removed by spraying oil - dispersing agents and spreading oil absorbing materials. Moreover, the oil pollution on the silt shoreline and the sandy coastline is not easy to keep for a long time under the action of waves and wind. It can be easily removed by bioremediation and sea wave action.

To sum up, the cleaning methods for coastal oil spill pollution are affected by many factors. The different types of coast, oil spill cleanup programs also have great differences, but should follow the following principles in the selection of specific cleaning method: (1) Must give priority to the protection the coast that has the highly sensitivity index , vulnerable to the oil spill damage the coast. (2) In the process of oil spill cleaning, it should take into account the actual situation, give priority to the technology that can remove large amounts of oil pollution, but will not cause serious damage, protect the ecological environment of the polluted coastal areas and avoid secondary pollution.

7.22 For the high incidence area of oil spill (Jiaozhou Bay, channel)

Qingdao municipal government should be reasonable planning of port construction, reasonable layout of waterway routes and roads, optimize the navigation environment, reduce the ship crossing and encounter probability, reduce the probability of ship oil spill accidents and pollution risk; improve the traffic system, assist large vessels to navigate safely within the fairway, and ensure the orderly navigation of ships entering and leaving the port. At the same time, should improve the infrastructure and

provide comprehensive navigation and navigational aids. Strict supervision of ships entering and leaving port. Improve the existing VTS (Vessel Traffic Services) system and enhance VTS monitoring in the areas where accidents are more frequently occour. In bad weather conditions, should take preventive measures; When the wind is large and the visibility is low, ships should be prohibited from entering and leaving the port. Also provide effective anchorage to help ship avoid typhoon. Improve the safety operation facilities and oil spill monitoring facilities, and regularly check and maintain these facilities. Check and maintain the navigation facilities regularly to ensure their safety and reliability.

7.23 For the high incidence area of oil spill (Huangdao dock and Dagang dock)

To standardize the management of dock, specific measures are as follows;

(1) Implement standardization and systematic of dock management system. The wharf management system, relevant operation regulations, equipment management, personnel training and related emergency plans shall be incorporated into the system, and a sound safety operation and pollution prevention management system will be established and improved.

(2) Improve the maintenance of equipment and facilities. For safety related equipment, emergency response and pollution prevention facilities, should be equipped in accordance with the relevant standards; The head of the wharf shall carry out regular maintenance and maintenance of these safety and antifouling equipment, and regularly check the electrical equipment, grounding facilities and berthing facilities so as to keep them in good working order.

(3) Carrying out standardized management of ship handling operation. For the existing port safety inspection system, the ship should strictly abide. Equipped with relevant duty personnel on duty and patrol, in time to understand the situation of the ship's operations and changes in the surrounding environment, so as to ensure the safety the ship and port. After the ship berthed, before carrying on the handling operation,

must be laying oil booms to prevent the spread of cargo or ship leaks; In this time, the vessel, piping, valves and other related equipment shall be checked to make sure these are in good condition and to check whether the mooring is safe or not. For small oil spill accidents, there should be corresponding prevention and plugging facilities, as far as possible to prevent the expansion of leakage incidents. For these places where oil spills are likely to occur, emergency equipment such as suction felt should be provided. (4) Make full use of modern monitoring facilities, ship berthing and loading and unloading operation remote monitoring, once found dangerous situation, timely treatment, to prevent the spread of the situation.

7.24 Strengthen the training and professional education of employees

(1) More stringent requirements on the crew of ships carrying dangerous goods. Not only required to hold the certificate issued by the navigation management institutions, but also through the corresponding training of the various certificates. For its technical requirements, the crew shall be able to be familiar with the relevant safety knowledge and safe means of operation of the dangerous goods contained in it, and to know in advance its dangers, possible harm and preventive measures.

(2) To the terminal management personnel and operation personnel, not only requires them to certificates, but also in the future work, it should be further training, daily should regularly overflow oil accident emergency drill. Regularly or irregularly organize terminal management personnel, operating personnel and other related personnel to participate in different oil spill accident’s training and exercises. To enable them to grasp the different conditions of oil spill emergency response knowledge and technology. Continuously improve the staff's skills in wharf safety operation and antifouling emergency response. Ensure that they are able to take effective action in accordance with emergency plans when an accident occurs.

(3) Safety education of port and dock staff is carried out to enhance their awareness of antifouling and regulate their operation behavior, so as to prevent the occurrence of oil spill pollution caused by human factors to the maximum extent.

7.25 Emergency measures for oil spills

If the oil spill occurs, it will cause serious harm to the Marine ecological environment, the port and the adjacent waters. If the treatment is not timely, there is also the possibility of an explosion, it will endanger the safety of the personal property. In order to protect the marine ecological environment and port environment, to ensure the safety of life and property, the greatest degree of reducing the harm of oil spill accidents, Qingdao government should set up oil spill emergency response system and emergency command department.

Once an oil spill occurs, the emergency system for oil spill accident shall be started. The concrete steps are as follows.

(1) The staff should immediately use wireless or wired phone report the specific situation, including the time and place of oil spill, the type of oil spill, the quantity, the cause of oil spilled, the meteorological and hydrological conditions, etc. are reported to the relevant departments. and the oil spill rescue operations are organized and carried out. If the oil spill is serious, it should report to the Qingdao maritime bureau and the municipal government.

(2) Confirm the responsible party of the accident and order the responsible party of the accident to take possible emergency measures to minimize the speed of oil leakage and to reduce the amount of oil leakage.

(3) At the same time, after receiving the accident report, the relevant departments to take prompt measures to rescue, according to the type, quantity, location, cause of oil spill, to assess the scale of oil spill, the oil spill accident scale as the basis, to determine the emergency plan for oil spill accidents; Reasonable arrangements for emergency prevention and control team and oil spill recovery ships, equipment, and the necessary

logistical support. When the oil spill accident is serious, may occur when the fire, should inform the relevant aspects of starting the fire emergency plan. In addition, the ship should be dispatch to the site of the oil spill accident and the surrounding seawaters to carry out the vigilance. According to the weather, wind direction, water flow and tidal current in the oil spill area, the direction of oil spill diffusion is controlled, and the oil spill is monitored and tracked to control the specific oil spill pollution. (4) According to the actual situation at the scene, formulate corresponding emergency response plan. In the early stage of oil spill or the amount of oil spill is not much, and the influence of wind and tide is smaller , The method of encircling spilled oil sources can be adopted, use the oil fence to surround the spilled oil to prevent further diffusion. If there is any possibility of oil spilling from the oil fence due to wind and tidal currents, two oil fences may be laid. In the event of large-scale oil spill, different methods of oil spill recovery should be used. When necessary, use oil spill dispersant to prevent and control oil spill contaminated seawaters.

(5) After an oil spill, it should be monitored for the surrounding sea areas, coastal areas and environmentally sensitive areas. Protective measures may be taken against threatened shoreline, environmentally sensitive areas and vulnerable resources.

Summary: the relevant departments of the port should prevent oil spill accidents to the utmost extent. Once the oil spill occurs, the oil spill emergency plan should be formulated quickly. Reduce the damage of oil pollution to the harbor and avoid secondary pollution.

7.3 Conclusion

Through the above analysis and research, this paper believe that the study of oil spill pollution in Qingdao port can promote the prosperity and development of Qingdao shipping industry and protect the Marine environment in Qingdao.

With the rapid development of global economy, enhance the strength of the shipping industry. The volume of oil transportation in Qingdao and the number of ships entering and leaving the port are also increasing. so the Qingdao port faced the oil spill risk also showed a significant growth trend. This paper analyzes the specific aspects of the economic loss caused by oil pollution to the port, and puts forward some suggestions based on the results. It is hoped that these suggestions can provide references for the prosperity of Qingdao port.

However, there are also shortcomings in this paper. Firstly, there are many reasons for oil spill pollution in Qingdao port. This issue involves a wide range of knowledge, some reasons may not be mentioned in this paper. In addition, it is necessary to verify whether the measures to prevent and control oil spill pollution are reasonable.

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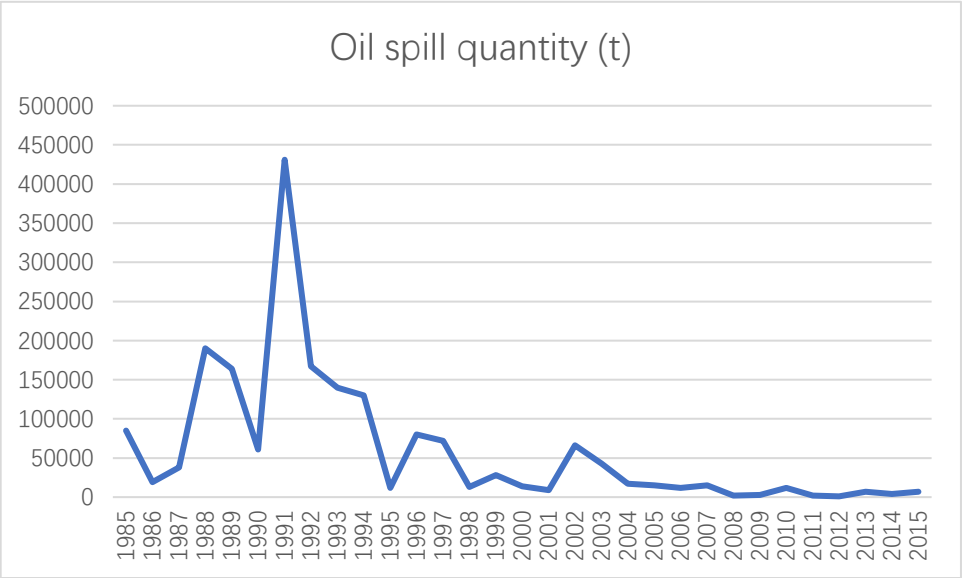
Appendix 1–Annual spilled oil quantity



Source: The website of The International Tanker Owners Pollution Federation

Appendix 2–Classification of oil spill accidents from 1970 to 2015

（<7t oil spill accidents）

Operation					
	Loading and unloading cargo	Fuel filling	Other operation	Unknow	Total
	3170	574	1286	2844	7874
Leakage reason					
Ship grounding	3	2	15	168	188
Ship collision	2	0	15	223	240
Hull damage	325	10	47	195	577
Equipment failure	1130	108	251	203	1692
Fire / Explosion	50	5	36	83	174
Others	842	291	518	164	1815
Unknow	818	158	404	1808	3188
Total	3170	574	1286	2844	7874

Source: The website of The International Tanker Owners Pollution Federation

Appendix 3–Classification of oil spill accidents from 1970 to 2015

（7-700t oil spill accidents）

Operation					
	Loading and unloading cargo	Fuel filling	Other operation	Unknow	Total
	393	32	178	761	1364
Leakage reason					
Ship grounding	5	0	57	299	361
Ship collision	0	0	26	244	270
Hull damage	37	4	15	45	101
Equipment failure	145	6	17	39	207
Fire / Explosion	9	0	13	25	47
Others	98	13	36	28	175
Unknow	99	9	14	81	203
Total	393	32	178	761	1364

Source: The website of The International Tanker Owners Pollution Federation

Appendix 4–Classification of oil spill accidents from 1970 to 2015

（>700t oil spill accidents）

Operation								
	Drop anchor (inland)	Drop anchor (open water）	On the voyage (inland)	On the voyage (Open water)	Loading and unloading cargo	Fuel filling	Other	Total
	16	9	81	299	42	1	81	459
Leakage reason								
Ship grounding	6	5	34	66	2	0	23	136
Ship collision	5	1	46	68	2	0	28	150
Hull damage	2	1	0	49	0	0	8	60
Equipment failure	0	0	0	6	11	0	1	18
Fire / Explosion	22	1	2	5	13	1	8	52
Others	1	0	0	14	8	0	7	30
Unknow	0	0	0	1	6	0	6	13
Total	16	9	81	229	42	1	81	459

Source: The website of The International Tanker Owners Pollution Federation