8-28-2016

Research on supervision countermeasures on ship sewage pollution

Baoxing Shen

WORLD MARITIME UNIVERSITY

Dalian, China

RESEARCH ON SUPERVISION COUNTERMEASURES ON SHIP SEWAGE POLLUTION

By

SHEN BAOXING

The People's Republic of China

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

MASTER OF SCIENCE

(MARITIME SAFETY AND ENVIRONMENTAL MANAGEMENT)

2016

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.

(Signature): ……Shen Baoxing……

(Date): ……03 August, 2016……

Supervised by: Cheng Dong

Professor

Dalian Maritime University

Assessor: …….

Co-assessor: ……..

ACKNOWLEDGEMENTS

First of all, I would like to take this opportunity to express my sincere appreciation to all the professors and mentors from Dalian Maritime University (DMU) and World Maritime University (WMU), who taught me a lot during my study in Dalian. I am also sincerely grateful to all the leaders of Wu Song Maritime Safety Administration (MSA) for giving me the chance to study in Dalian. Particularly, I would like to thank the director general of Wu Song MSA, Zhu Guobing, who strongly supported me to purse this off-work study after ten years of graduation. Also, I appreciate his help to me both in life and study.

I am very thankful to Prof. Cheng Dong, who not only gave us lectures with a very strong sense of responsibility, but also took us to visit the engine laboratory in DMU. Most important of all, as my supervisor, he offered me so many invaluable advices before I start writing. Meanwhile, he provided me a lot of guidance in the whole process of writing. His expertise and rigorous attitude left a deep impression on me.

I also deeply appreciate all my colleagues in Wu Song MSA for their selfless help and support during my study in Dalian, and they took extra tasks which should have been done by me. I would like to thank Xv Yongfeng, a chief engineer, who is very familiar with the inner structure and daily management of sewage treatment plant, for giving me a lot of guidance and enlightenment.

Last but not least, I would also like to thank my beloved parents-in-law, they provided their full support to care the whole family, which encouraged me to study in Dalian without the worries behind, especially my dear wife, who tolerated my long absence and offered her maximum support and encouragement to me.

ABSTRACT

Title of research paper: **Research on Supervision Countermeasures on Ship Sewage Pollution**

Degree: **MSc**

There are thousands of ships engaged in international voyage all over the world and numerous coastal vessels and river vessels are sailing on coastal waters and rivers. These ships produce a large amount of sewage every day, and some untreated sewage is illegally discharged into port waters and coastal waters, which violates the requirements of the pollution prevention convention and causes serious pollution to marine environment.

This research paper mainly concentrates on the issue of ship sewage pollution. After briefly introducing the background of research topic, the author points out the damage of sewage to marine environment and relevant requirements of pollution prevention convention, illustrates different working principles of different treatment plants, as well as advantages and disadvantages. Furthermore, the author focuses his attention on analyzing the reasons of illegal discharge of raw sewage, and explaining how to carry out PSC inspection to sewage treatment plant. Finally, the author proposes dozens of specific solutions from different aspects to change the current situation.

KEY WORDS: ship sewage, pollution prevention, illegal discharge, comminuting and disinfecting system, holding tank, activated sludge treatment plant, annex IV, MARPOL, PSC

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

WTO	World Trade Organization
GDP	Gross Domestic Product
IMO	International Maritime Organization
PSC	Port State Control
MSA	Maritime Safety Administration
BWM	International Convention for the Control and Management of Ship's Ballast Water and sediments 2004
CLC	Protocol of 1992 to amend the International Convention on Civil Liability for Oil Pollution Damage, 1969
ORPC	International Convention on Oil Pollution Preparedness, Response and Co-operation 1990
FUND	Protocol of 1992 to amend the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971
AFS	International Convention on the Control of Harmful Anti-Fouling System 2001
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto
CO_2	Carbon dioxide
VOC	Volatile Organic Compounds
BOD	Biochemical Oxygen Demand
SS	Suspended Solid
ISPP	International Sewage Pollution Prevention Certificate
MBR	Membrane Bioreactor
MEPC	Maritime Environmental Protection Committee

Chapter 1: Introduction

1.1 Background:

After the Second World War, the world economy began to recover quickly, and the cargo transportation between nations and regions are more frequent than ever before. Especially in the last few decades, with the increasing internationalization of production and commodity, international trade-in-service has developed at an amazing speed on a global scale, and the growth of world trade between 1950 and 2008 is shown in the figure 1.

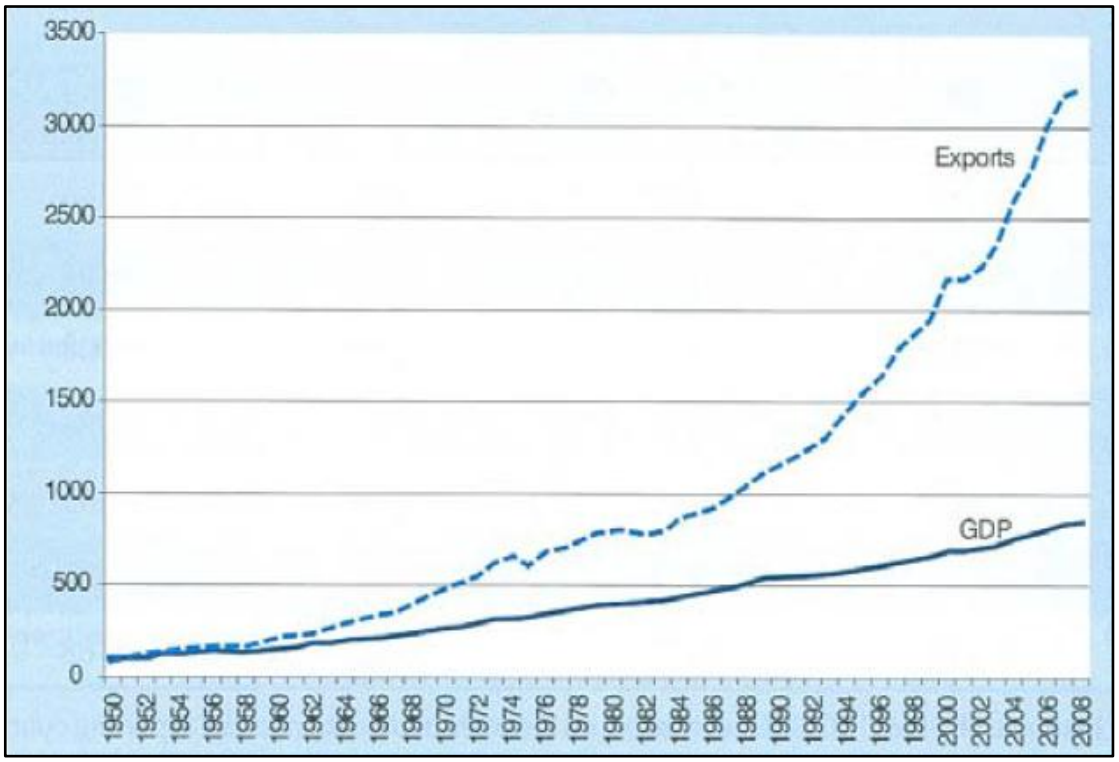


Figure 1: Annual Growth of World GDP and Trade 1950 – 2008

Source: WTO World Trade Development 2011

It is generally known that almost 90% of world freight is transported by ships. As the

main transportation mode, the shipping industry has played an extremely important role in the transportation of goods. Along with the world economic globalization and the rapid development of world trade, the shipping market presented a prosperous scene in recent years, and the specific growth rate is shown in figure 2. According to the relevant statistics from IMO, there are about 50,000 merchant ships in operation at present, which are registered in more than 150 countries (Sun, 2015, p.1). That is to say, there are thousands of ships entering in or departing from various ports in the world.

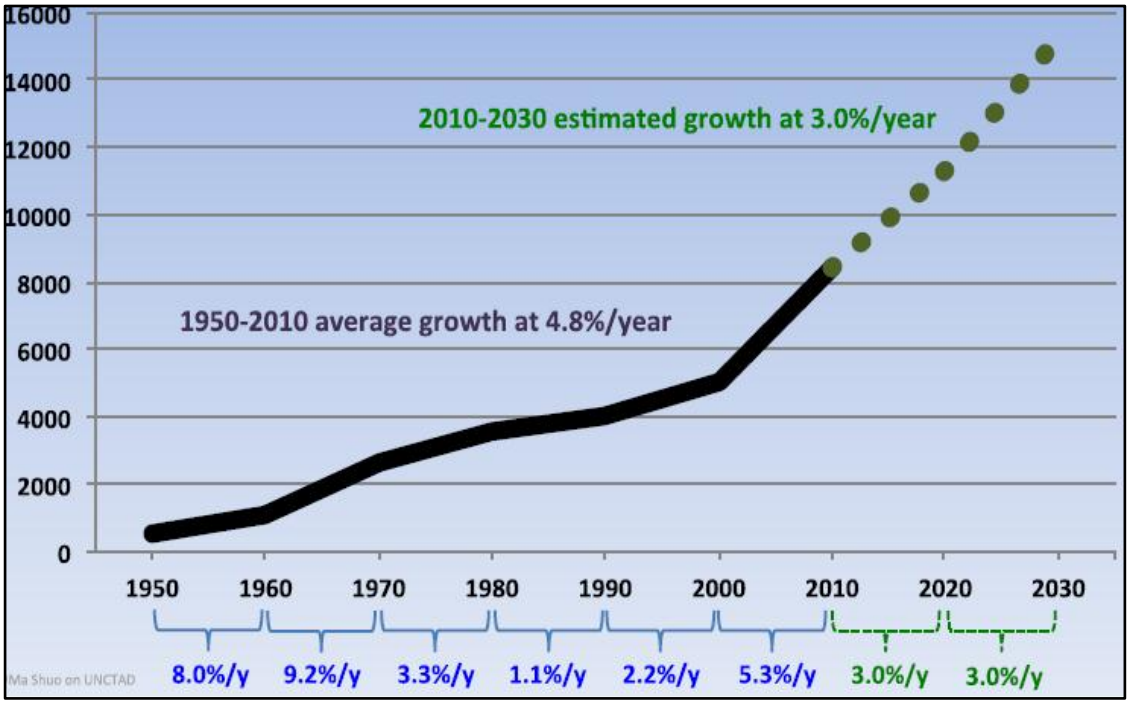


Figure 2: World International Seaborne Trade 1950-2010 and Estimate to 2030

Source: compiled by Ma shuo, Maritime Economics

With the increase of the number of ships, the pollution of the marine environment has become more and more serious in recent decades, due to the pollutants discharged by ships in the process of operation. An investigation report from the US National Academy of Sciences indicated that approximately 35% of the pollutants in

the marine environment were from ships in 2002 (Wang, 2008, p.49), so the shipping was once deemed to be the least environmentally damaging mode of transport. However, because of the advantages of large load capacity and low cost, the heavy bulk commodities traveling long distances, such as grain, coal, chemicals, and raw ore, could not be transported any other way than by ships.

It is true that a variety of pollutants will be produced in the course of the operation of the ships, such as various oils, garbage, sewage, VOCs, CO_2, etc. which will cause serious pollution to the marine environment. A cargo ship will produce at least 50kg garbage including the food waste every day in accordance with relevant statistics, most of which is discharged into ocean directly without any treatment. It is estimated that more than 10,000 tons of ship garbage including food waste is discharged into ocean every day (Xv, 2003, p.30). Similarly, ship raw sewage is also a major marine pollutant; the China Ministry of Environmental Protection predicts that more than 15 million tons ship sewage is discharged into Three Gorges Reservoir area each year (Da, 2007, p.137).

With the development of shipping industry and enhancement of social marine environmental protection awareness, people pay more and more attention to the marine environmental pollution caused by ships. In order to reduce pollution and protect marine environment, almost all coastal states have formulated laws and regulations to limit the discharge of pollutants from ships. Meanwhile, the IMO has also developed a series of conventions to regulate the transport services of ships, which covered the entire life cycle of the ship from shipbuilding to ship recycling (Wei, 2014, p.40), and the specific documents are shown in the table1.

After a series of conventions from IMO, some of the emissions of pollutants have

been initially curbed, such as oils; there is a clear decline in the discharge of oil on board, regardless of accidental discharge or operational discharge. But the decrease of discharge of some pollutants has not kept the same pace with that of oils, for example the ship sewage. Relevant treatment requirements of ship sewage are clearly defined in the annex IV of MARPOL convention, which has entered into force a few years ago. However, in practice, the implementation of the annex IV is highly unsatisfactory, especially in developing countries and undeveloped countries. In other words, there is still a large amount of ship sewage unlawfully discharged into ocean annually, even in developed countries and special areas. Most of discharge actions are contrived and deliberate, rather than legal disposal in accordance with requirements of convention.

Table 1: the Major conventions relating to the prevention of pollution

Number	Name of Conventions	Effective Date
1	MARPOL 73/78	2nd of October 1983
2	BWM Convention	Not yet in effect
3	INTERVENTION Convention	6th of May 1975
4	CLC Convention	19th of June 1975
5	OPRC Convention	13th of May 1995
6	FUND Convention	11th of October 1978
7	Bunker Convention	21st of November 2008
8	AFS Convention	17th of September 2008
9	Hong Kong Convention	15th of May 2009

Source: compiled by author based on information searched from IMO website

1.2 Objectives of the research

The above mentioned background implies the urgency and necessity of strengthening

the implementation of annex IV of MARPOL convention on the global scale. The author, as the deputy section chief of dangerous goods management and pollution prevention department in Wusong MSA, has been engaged in PSC and anti-pollution inspection for several years. In the actual inspections, the author has found and punished a large number of illegal acts of discharging ship sewage into ocean. Therefore, in this research paper, the author will analyze the reasons of the poor implementation of annex IV of MARPOL convention in detail, and then give personal suggestions to strengthen the management of ship sewage combined his previous work experience. The main objectives are as follows:

1. Attract people's attention to the issues discussed in this research paper
2. Compare the pros and cons of current main treatment methods of sewage
3. Enumerate the problems in disposal and discharge of sewage
4. Analyze the reasons of illegal discharge of ship sewage
5. Give the main points in PSC inspection about sewage treatment plant
6. Offer the suggestions for strengthening the management of sewage

1.3 Methodology

The relevant document literature was widely collected and reviewed beforehand; including search results from IMO website, such as international convention, circulars and documents, resolutions, amendments, and so on. Besides, some materials and literatures are from periodicals, books, contemporary journals, others' graduation thesis or dissertation, as well as internet. Furthermore, opinions were exchanged with some senior PSC officers and pollution accident investigator, and some suggestions and advice from them were adopted and collected in this research paper. In addition, as a PSC officer and anti-pollution inspector, the author's own

previous work experience also played a big role, and the theory was connected with practice in the process of designing this research paper. In brief, this research paper essentially concentrates on the issue discussed using the methods of consultation and investigation, putting the theory with practice together, literature researching, case study, logical analysis and induction, network browsing, quotation data, and chart analysis.

1.4 Chapter summary

In sum, the marine environmental pollution caused by ship sewage has not been paid to as much attention as oils; at least it is not enough at present. Although the regulations for prevention of pollution by sewage from ships have incorporated into MARPOL convention, many countries cannot yet give full and complete effect to these regulations for various reasons, which result in the poor implementation of the annex IV of MARPOL convention. The pollution of marine environment is gradually deteriorating with a large amount of ship sewage illegally discharged into ocean.

Chapter 2 Hazards and treatment requirements of ship sewage

2.1 Definition of ship sewage

According to the regulation 1 of annex IV of MARPOL convention, four kinds of waste water are defined as ship sewage (IMO, 2003), they are:

1. drainage and other wastes from any form of toilets and urinals;
2. drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises;
3. drainage from spaces containing living animal;
4. other waste waters when mixed with the drainage defined above

Generally speaking, waste water from ships can be divided into two kinds, namely black water and gray water. The black water is the above defined sewage, which must be treated in accordance with disposal requirements before discharge; and the gray water means the water drained from galley, bathroom and laundry room, which is considered to be less harmful to the marine environment and is not necessary to be treated before discharging into ocean.

However, as people gradually increase the awareness of marine environmental protection, some countries and areas have put the gray water into the category of sewage in recent years, so both the black water and gray water are called ship sewage uniformly. In other words, the gray water also needs to be treated with sewage treatment plant and must meet the required standard of IMO before discharging into ocean. At present, some ships have transformed the layout of pipeline, so that the gray water can also flow into sewage treatment plant.

2.2 Hazards of ship sewage

The damage of sewage is not as serious as oils, but it still can do a great harm to the marine environment. Ship sewage is different from municipal wastewater. To begin with, ship sewage cannot be fully decomposed in the ship sanitation system due to the shorter discharge cycle. Furthermore, compared with the residential sanitary ware in urban area, ship sanitary ware (close-stool) uses less flushing water, so the BOD and SS index of ship sewage is higher than municipal sewage. Consequently, the ship sewage is normally more harmful to the marine environment than municipal wastewater.

Ship sewage contains a large amount of human feces and urine. If this kind of sewage is discharged into ocean directly without any treatment, the organic matter in sewage will consume dissolved oxygen in water when they are oxidized and decomposed in the biochemical action of microorganisms, which will lead to the lack of oxygen in the sea water. Consequently, many aquatic animals and plants will die due to lack of oxygen. After the animals and plants die, the dead bodies will become new organic matter and will be also oxidized and decomposed, which will form a vicious circle. At last, the concentration of dissolved oxygen in water is greatly reduced, and anaerobic conditions are formed. The advanced form of the biological community is replaced by the lower form, and the marine environment will be seriously damaged.

Under normal circumstances, sea water itself has a slow process of self-purification, and the process of self-purification will be difficult to restore once it is disrupted. It is thought that human feces and urine contains more nitrogen and phosphorus and other nutrients. So if the ships sewage containing human faces and urine is

discharged into ocean directly without any treatment, this kind of sewage will lead to excessive growth and reproduction of algae and phycophyta, as well as the formation of eutrophication of sea water, especially in lakes, estuaries and bays and other areas where the water cycle is relatively slow. Considering the water eutrophication which will seriously damage the delicate balance of self-purification, the regional marine environment will be polluted and destroyed.

Besides, a lot of viruses and bacteria exist in the ship sewage containing human feces and urine, in particularly the Escherichia coli and cholera virus; these bacteria and virus will seriously affect the hygienic index of sea water. Once human beings drink this kind of water, it is very likely to result in the prevalence and spread of the disease, such as dysentery, enter gastritis, cholera, acute infection and so on. If this kind of sewage is discharged into mariculture zone or protected region of drinking water source, this problem will be more striking and serious. In addition, if ships discharge sewage into coastal waters, it would have a great impact on the coastal tourism area and seaside sanitarium.

2.3 Treatment requirements of ship sewage

IMO began to pay close attention to the marine environmental pollution caused by sewage a few years ago. After many years' efforts, relevant regulations for the prevention of pollution by sewage from ships were integrated into MARPOL convention and became annex IV. This annex entered into force on 27 September 2003, a revised Annex IV was adopted on 1 April 2004 and entered into force on 1 August 2005.

2.3.1 Application for ships

According to relevant provisions of regulation 2 of chapter 1 of annex IV, all of the ships engaged in international voyages must equip with a certain sewage system if the ship's gross tonnage is equal to or more than 400 gross tonnages or the ships are certified to carry more than 15 persons. With certain exceptions enumerated in Regulation 3, all of the sewage from ships should either be disposed or comminuted and disinfected as required before discharge or delivered to reception facilities in shore.

2.3.2 Requirements for sewage systems

Every ship which meets the requirements of regulation 2 of annex IV should be equipped with one of the following sewage systems in accordance with the relevant provisions of regulation 9 chapter 3 (IMO, 2003):

1. A sewage treatment plant. The plant shall be of a type approved by the administration of contracting government, taking into account the test methods and standards formulated by IMO.
2. A sewage comminuting and disinfecting system. Similarly, this system shall be approved by the administration of contracting government. Meanwhile, the system shall be fitted with equipment and facilities to the satisfaction of administration of contracting government, and this system shall be available to store the sewage temporarily when the ship is less than 3 nautical miles from the nearest land.
3. A holding tank. The capacity of holding tank shall be enough to store all sewage from ship and should have a means to indicate visually the amount of its contents. Besides, the holding tank is built after regarding to the operation of the ship, the number of persons on board and other relevant factors, as well

as the holding tank shall be constructed to the satisfaction of the administration of contracting government.

2.3.3 Requirements for discharge of sewage

Generally speaking, the discharge of sewage into the sea is prohibited with a few exceptions, such as force majeure, salvage. But in the following circumstances the discharge of ship sewage is permitted (IMO, 2003).

1. The ship is discharging disinfected and comminuted sewage using a system approved by the administration of contracting government in accordance with regulation 9 of chapter 3 of annex IV at a distance of more than 3 nautical miles from the nearest land, or discharging sewage which is not disinfected or comminuted at a distance of more than 12 nautical miles from the nearest land. However, under any circumstances, the sewage stored in holding tanks and the sewage coming from spaces containing living animals shall not be discharged instantly but at a moderate rate when the ship is in sailing at not less than 4 knots. In addition, the discharge rate shall be approved by administration of contracting government based upon standards developed by IMO.

2. The ship has an approved sewage treatment plant which has been certified by the administration of contracting government. Meanwhile, the treatment plant is in operation in accordance with the operational requirements listed in regulation 9 of chapter 3 of annex IV. Besides, the test result of treatment plant should be written down in the ISPP of the ship, and the effluent shall neither form visible floating solids nor result in discoloration of the

surrounding water.

3. The above provision 1 shall not apply to the ships only operating in the waters under the jurisdiction of certain state as well as the visiting ships from other states. These ships are permitted to discharge sewage into waters under the jurisdiction of certain state according to relatively less stringent requirements developed by this state.

.4 If the sewage is mixed with wastes or waste water covered under other annexes of MARPOL convention, the disposal and discharge requirements of other annexes shall be taken into account in addition to the requirements of this annex before discharging this kind of sewage.

2.3.4 Requirements for reception facilities of port state

The ship must transfer sewage stored in holding tanks to reception facilities on the shore in some cases, for example treatment plant failure, the capacity of holding tank is not enough when the ship stays at the port for a long time. In order to facilitate the ships to discharge sewage into reception facilities and protect marine environment, IMO develops special regulations for reception facilities and requires each contracting government to undertake corresponding obligations, that is each port and terminal shall provide reception facilities which should meet the needs of the ships arriving at this port and terminal without causing delay to ships.

The diameter of discharging pipeline on the vessel is not the same as the diameter of the receiving facility sometimes. In order to enable pipes of reception facilities to be connected with the ship’s discharge pipeline, IMO requires both ships and reception

facilities to fit with a standard discharge connection at least. The parameters of the standard discharge connection are shown in the table 2 (IMO, 2003).

Table 2: Standard dimension of flanges for discharge connections

Description	Dimension
Outside diameter	210 mm
Inner diameter	According to pipe outside diameter
Bolt circle diameter	170 mm
Slots in flange	4 holes, 18 mm in diameter, equidistantly placed on a bolt circle of the above diameter, slotted to the flange periphery. The slot width to be 18 mm.
Flange thickness	16 mm
Bolt and nuts: quantity and diameter	4, each of 16 mm in diameter and of suitable length
The maximum internal diameter of flange should be less than 100 mm, designed by steel or other equivalent material having a flat face. The flange, shall be suitable for a service pressure of 600 kPa, together with a suitable gasket, the inner diameter of the discharge connection may be 38 mm for ships having a moulded depth of 5 m and less.	

Source: compiled by author based on material searched from MARPOL convention

2.4 Chapter summary

In brief, this chapter tersely reviews the definition of sewage, the hazards of sewage and requirements for discharge. Ships produce a large amount of sewage on a daily basis, and it goes without saying that ship sewage has great harm to the marine environment, despite that the harms are not as serious as oils. Consequently the IMO developed a series of requirements and regulations, and ships must operate in accordance with the requirements to reduce damage to marine environment.

Chapter 3: Treatment methods of ship sewage

Tens of thousands of ships sail on the sea every day. If all of sewage generated on the ships is discharged into the ocean, the harm of sewage to the marine environment will be very great. People have begun to pay close attention to this problem at an unconscionably early age and attempted to come up with a variety of methods to reduce the harm. At present, there are three main methods to dispose the ship sewage on board in practice; they are the holding tanks, the comminuting and disinfecting system, as well as the treatment plant.

3.1 Holding tanks

One or more holding tanks are set up on the ship, and all of sewage is discharged into the holding tanks during the course of the voyage. If the holding tanks are full, the sewage will be discharged into reception facilities on shore when the ship is in port. The flow chart is shown in figure 3.

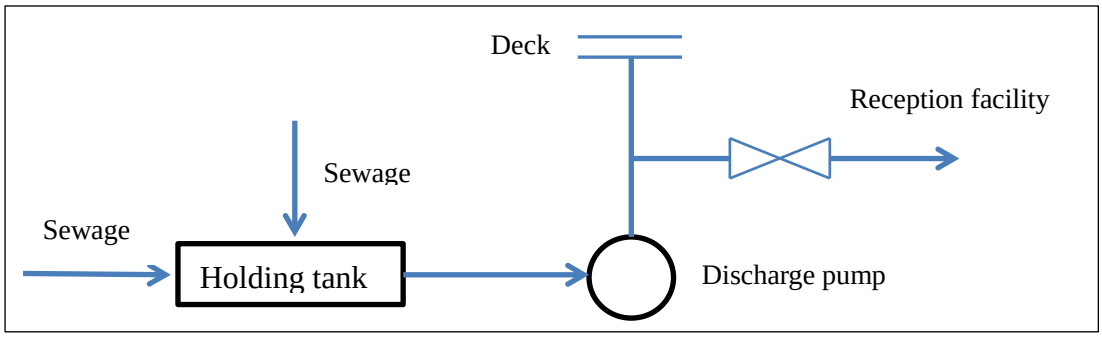


Figure 3: the flow chart of holding tank

Source: compiled by author based on the operating principle of holding tank

Advantages: this system is simple in structure, and it is easy to operate and manage for crewmembers. Furthermore, all of sewage is stored in holding tanks,

rather than discharged into ocean directly, so that it will not cause pollution to the marine environment.

Disadvantages: when the ship sails at sea for a long time, the capacity of holding tank must be large enough to hold all of the sewage, which will lead to reduction of cargo capacity and operational efficiency. Moreover, all of the sewage is stored in holding tank for a long time; the bad smell will pose an impact on crewmembers' living environment and working environment.

3.2 Sewage comminuting and disinfecting system

Besides the holding tanks, ships can also choose to install the sewage comminuting and disinfecting system, and the floating matters and solid residues are crushed and sent to the incinerator to be burned. After disinfection, other sewage is discharged into ocean at the waters where is in accordance with the requirements of MARPOL convention. The flow chart is as follows.

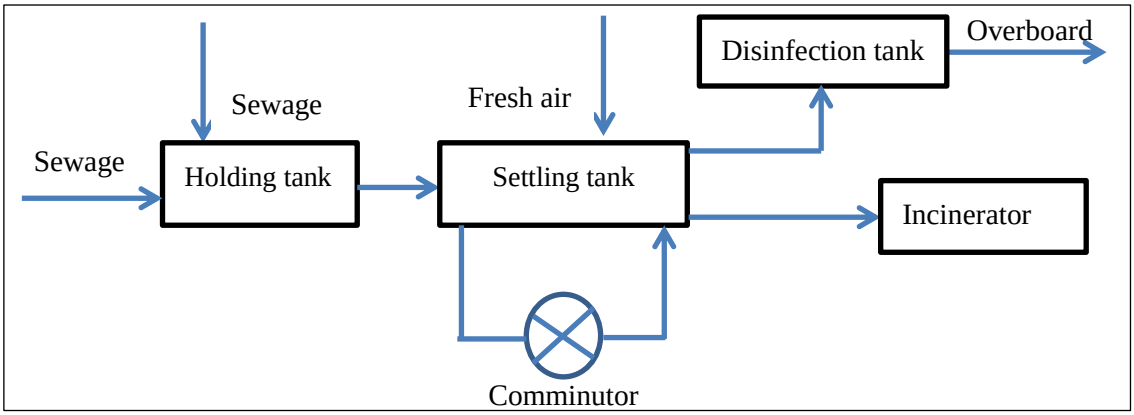


Figure 4: the flow chart of comminuting and disinfecting system

Source: compiled by author based on the operating principle of sewage comminuting and disinfecting system

Advantage: this system is relatively simple, and it is also easy to operate and manage for crewmembers. Because the sewage is discharged timely after disinfection, it does not need much space for this system. Therefore, it can save more space for cargo and goods.

Disadvantage: shipping company needs to spend money on buying disinfection tablets, which will increase the operating costs of the ship. In addition, the discharge area of ship sewage is restricted for the ships using this kind of comminuting and disinfecting system according to 11 regulation chapter 3 of annex IV of MARPOL convention. It is allowed to discharge sewage into ocean only at a distance of more than 3 nautical miles from the nearest land, so this system is not applied to the river ships and some of the ships in coastal areas.

3.3 Sewage treatment plant

If a ship has a sewage treatment plant on board and the treatment plant keeps in operation, the ship is permitted to discharge sewage into ocean almost anywhere in the world. Of course, the prerequisite is that the treatment plant has been approved by the administration of contracting state, taking into account the standards and test methods developed by IMO. Because of the outstanding advantages, the sewage treatment plant has been widely used in various kinds of ships, and the ships range from passenger ships to cargo vessels, from offshore ships to ocean going vessels. According to different working principles, the main methods of sewage treatment include high pressure oxidation treatment, physical and chemical treatment, electrochemical treatment, biological treatment, as well as the combination of the aforementioned methods.

3.3.1 High pressure oxidation treatment

The ship sewage is collected in holding tanks firstly, and then discharged into an aeration tank by pump after full mixture. The high pressure air is imported into sewage and a chemical reaction takes place between the air and the organic matters in the sewage with the help of catalyst. Methane and other gases will be produced during oxidation of the organic matters; the gases are collected or discharged into air after purification, the sewage will be fully oxidized and discharge into ocean, and the solid separated from the sewage will be burned in incinerator. The flow chart is shown in figure 5.

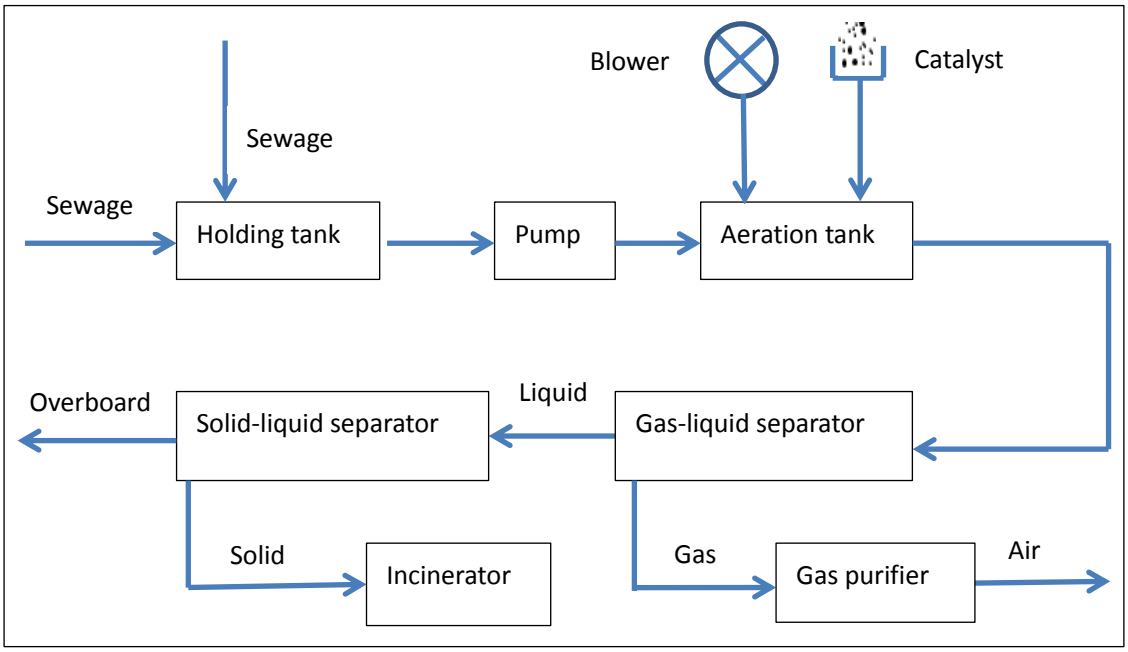


Figure 5: the flow chart of high pressure oxidation treatment plant

Source: compiled by author based on the operating principle of high pressure oxidation treatment plant

Advantage: this system is compact in structure and takes up less room, and it has a good effect on the treatment of ship sewage containing solids. The vast

majority of organic matter and bacteria in sewage can be destroyed through this system, so the treated sewage has basically no damage to the marine environment.

Disadvantage: the system needs to keep a high temperature and pressure during the oxidation of organic matters, which will lead to the increase of the energy consumption of the ship. Moreover, the shipping company needs to invest more money to purchase this system in the early stage because of its relatively higher price. Lastly, this system will discharge a large amount of exhaust gas in the process of sewage treatment, which may result in air pollution.

3.3.2 Physical and chemical treatment

After being discharged into holding tanks, the solid matters and SS in the sewage are eliminated through the process of precipitation, filtration, and agglomeration, and the main purpose of which is to reduce the index of BOD_5. The rest of sewage is discharged overboard after disposal of deoxidization and disinfection by activated carbon or other chemical agent, and the solid matters is sent to incinerator to burn or received by shore reception facilities. The flow chart is shown in figure 6.

Advantage: this system has a smaller size and takes up less room. In addition, the working principle of this system is simple and it is also easy to operate and manage for crewmembers.

Disadvantage: this system needs a lot of disinfectant and coagulant as well as other chemical agent, which lead to a high operating cost. Furthermore, the

pipe of this system needs to be cleaned regularly, or it will be blocked. In addition, the sewage will be stored in this system for a long time; the bad smell will pose an impact on crewmembers' living environment and working environment (Yuan, 2010, p.42).

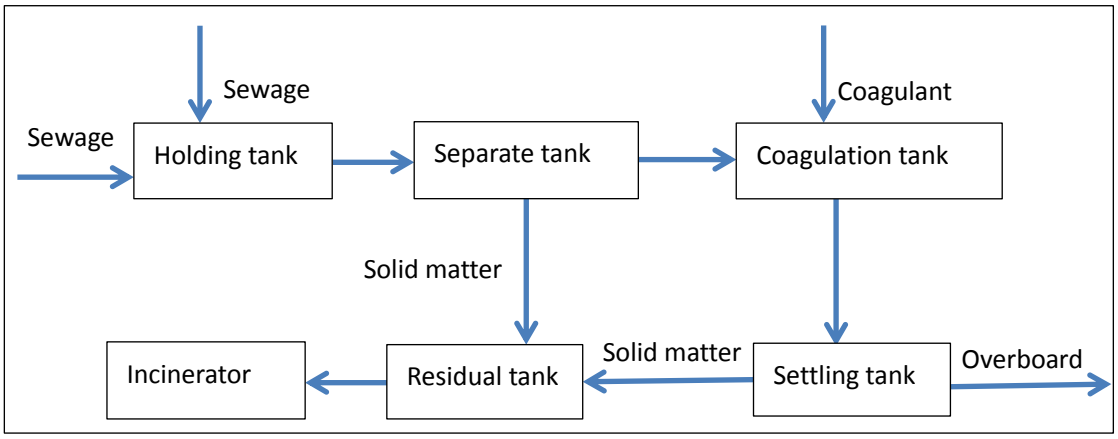


Figure 6: the flow chart of physical and chemical treatment plant

Source: compiled by author based on the operating principle of physical and chemical treatment plant

3.3.3 Electrochemical treatment

Firstly, ship sewage is preliminarily separated in separate tank. The residues and solid matters are sent into residual tank, and other sewage is discharged into electric coagulation tank, where the sewage is treated by electricity. After that, the sewage is discharged into floatation tank, and after disinfection, the sewage is discharged overboard and the residues and solid matters are burned in incinerator. The flow chart is shown in figure 7.

Advantage: The electrochemical treatment plant is small in size and light in weight, as well as high in efficiency of sewage treatment. Furthermore, it is also

easy to operate and manage for crewmembers, and it does not produce off-flavor in the process of sewage treatment.

Disadvantage: The initial investment of this kind of treatment plant is relatively high, and the daily operating cost is also higher than other kind of treatment plants. Meanwhile, the treated sewage contains a lot of chlorine, which will cause secondary pollution of marine environment (Yuan, 2010, p.42).

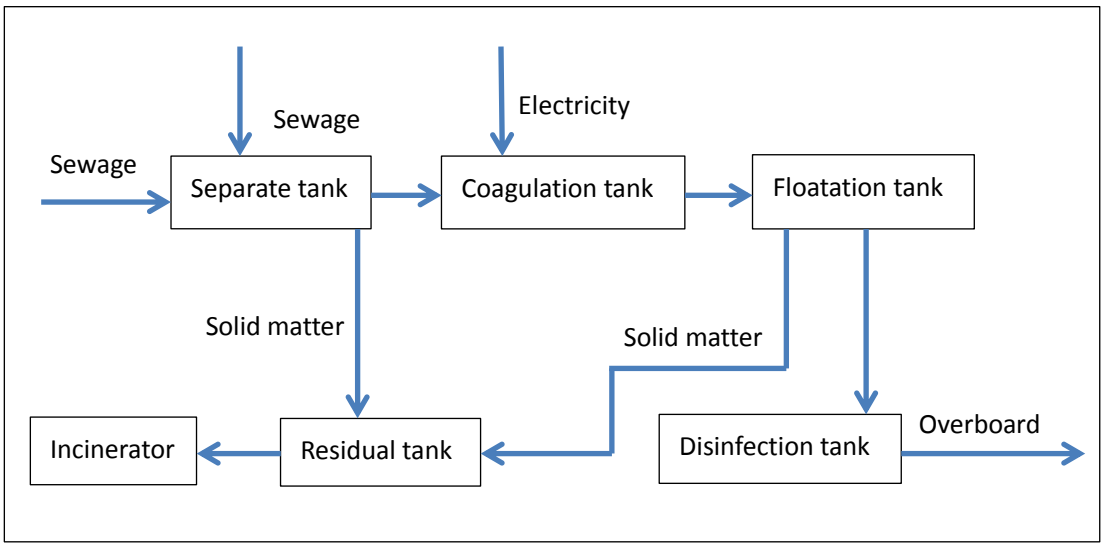


Figure 7: the flow chart of electrochemical treatment plant

Source: compiled by author based on the operating principle of electrochemical treatment plant

3.3.4 Biological treatment

Biological treatment has been proved able to dispose ship sewage via oxidizing and decomposing organic compounds by using microorganisms as the bio-catalysts. In actual operation, it needs to create an environment which is conducive to growth and

reproduction of microorganisms, because a large number of microorganisms are beneficial to increase efficiency of oxidation and decomposition of organic matter. At present, the activated sludge process and membrane bioreactor (MBR) are the two main methods of biological treatment in practice.

3.3.4.1 The activated sludge process

The activated sludge process is a kind of aerobic biological treatment method. The main working principle is that it uses activated sludge to absorb, oxidize and decompose the pollutants in the sewage under aerobic conditions, which makes the unstable organic compounds convert into stable inorganic compounds, thus purifying the ship sewage.

In practice, the untreated sewage is discharged into the aeration tank firstly, in which there are plenty of activated sludge; meanwhile, the blower sends the fresh air into the aeration tank. The activated sludge contains a large number of microorganisms, which can oxidize and decompose the organic compounds. Subsequently, the sewage is pumped into sedimentation tank, where the liquid and solid will be separated. Then the liquid will be discharged into disinfection tank and the solid will return into aeration tank. Finally the treated sewage is discharged overboard after disinfection and solid matters will be sent to incinerator to burn or received by shore reception facilities. Figure 8 is the flow chart.

Advantage: The initial investment in the purchase of the activated sludge treatment plant is smaller than that of other kinds of plants, and the operating cost is also low. In addition, the structure of this kind of treatment plant is so simple and it is also easy to operate and manage for crewmembers. In

particular, when the failure or disorder happens on this kind of plant, repair and maintenance are very convenient. Furthermore, the effect of sewage treatment is very good, and the treated sewage has almost no pollution to the marine environment (Yuan, 2010, p.42).

Disadvantage: This kind of treatment plant is larger in size and occupies a larger space in the engine room. Besides, the activated sludge treatment plant must be maintained continuously in use. Meanwhile, the blower also needs to continuously feed fresh air into the aeration tank, or the microorganisms in the sludge will die due to the lack of necessary nutrition, and it takes a long time to retrain the microorganisms.

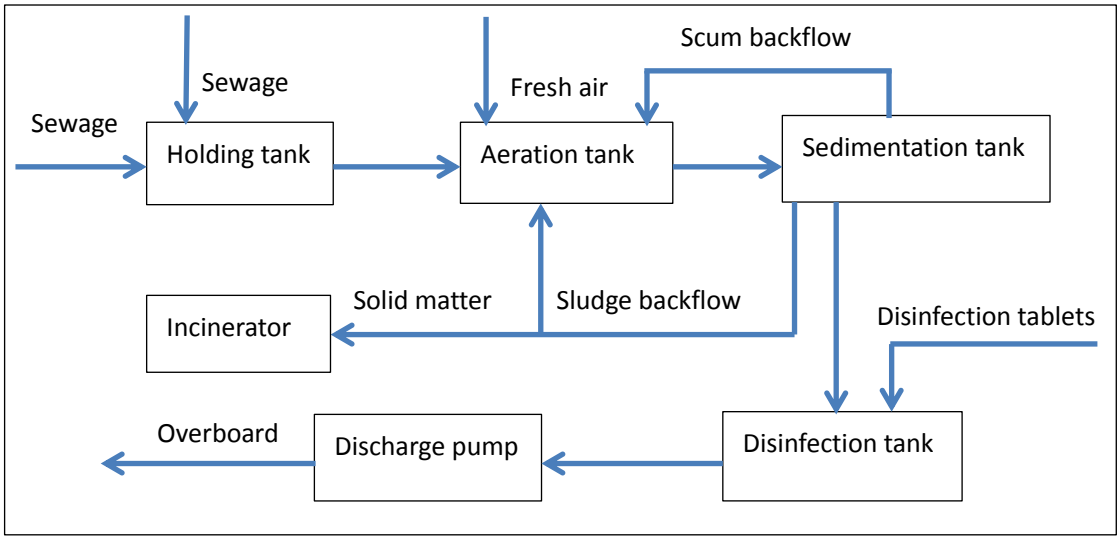


Figure 8: the flow chart of activated sludge process

Source: compiled by author based on the operating principle of the activated sludge treatment plant

3.3.4.2 The membrane bioreactor

The membrane bioreactor is a new sewage treatment method which has just appeared in recent years. The main working principle is that it uses advanced membrane separation technology on the basis of traditional biological treatment. The most obvious feature is that the membrane components replace sedimentation tank in the traditional biological treatment methods, because the filter membrane can separate liquid materials and solid matters and the separation effect is better than that of the sedimentation tank. The raw sewage is first biologically degraded in the bioreactor, and then the sewage is disinfected after filtration by membrane components. At last, the treated sewage is discharged overboard. The flow chart is shown in figure 9.

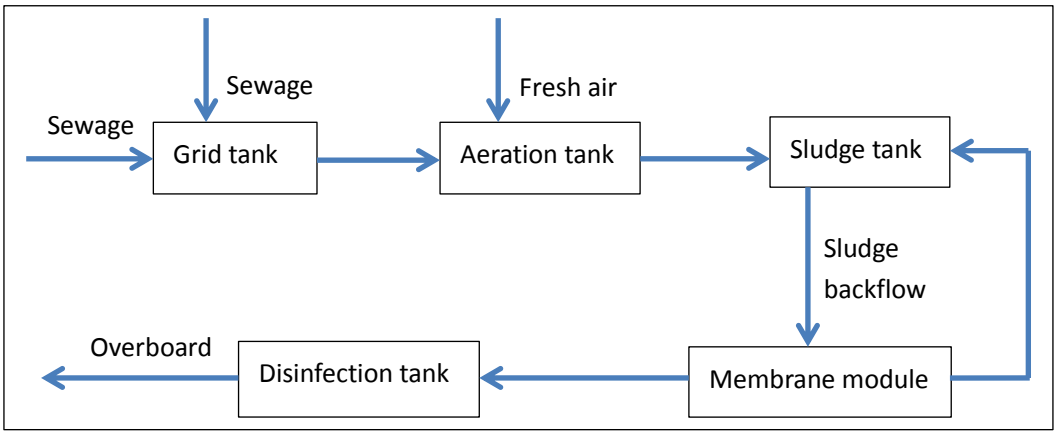


Figure 9: the flow chart of membrane bioreactor

Source: compiled by author based on the operating principle of membrane bioreactor

Advantage: The efficiency of solid-liquid separation is very high and the water quality of treated sewage is very good. Besides, the suspended solids and turbidity of the treated sewage are almost zero, even the treated sewage can be reused. In addition, because sedimentation tank are not required, this membrane bioreactor has a smaller size and takes up less room.

Disadvantage: The filter membrane needs to be replaced at fixed periods, so the

> operating cost is higher than that of the activated sludge method. Moreover, the activated sludge should be cultivated by professionals, and once the system is stopped over time, the sludge will lose activity. If the system is put into use again, the activated sludge needs to be re-cultivated (Yuan, 2010, p.42).

3.4 Chapter summary

In summary, this chapter briefly reviews three methods of ship sewage treatment. The first method—the holding tank, is mainly used in river vessels and coastal-going ships, and the time of continuous voyage is relatively short; the second method—the comminuting and disinfecting system, is rarely used alone, and in most cases it is used together with ship sewage treatment plant; the third method—sewage treatment plant, has been widely used on the ships because of its many advantages, in particular the sea-going ships.

Various sewage treatment plants are based on different working principles, and each has its advantages and disadvantages. However, the method which uses activated sludge to treat ship sewage is the most popular in shipping market, due to two most obvious advantages, namely less initial investment and lower operating cost. Particularly, the ship-owners prefer this kind of treatment plant above all others, and the market share of this kind of treatment plant is certainly the highest in the present shipping market.

In the following chapters, the author will take the sewage treatment plant based on activated sludge method for an example, further analyze and discuss the reasons for illegal discharge of ship sewage and main points of PSC inspection.

Chapter 4: Reasons for illegal discharge of ship sewage

4.1 Implementation of the annex IV of MARPOL convention

In order to protect marine environment, the IMO has developed special regulations to prevent pollution by sewage from ships. It is the annex IV of MARPOL convention, which has entered into force on 27 September 2003 around the world. In accordance with relevant requirements and provisions, all of the vessels engaged in international voyage shall equip with a certain sewage system if the vessel' gross tonnage is equal to or more than 400 gross tonnage and the vessel is certified to carry more than 15 persons. Besides that, all of the ship sewage shall either be disposed or comminuted and disinfected as requirement before discharge overboard or discharged into reception facilities in shore.

Every ship shall be equipped with one of the three sewage systems: they are sewage comminuting and disinfecting system, holding tank and sewage treatment plant. Currently, almost all of the vessels engaged in international voyage have the "double insurance"; in other words, most of the ships not only have the sewage treatment plant but also the sewage comminuting and disinfecting system or the holding tank. The main purpose is to ensure ship sewage to be disposed or discharged according to the regulations of the MARPOL convention theoretically. However, in practice, the implementation of the annex IV is unsatisfactory, especially in underdeveloped countries and developing countries. In other words, illegal discharge of ship sewage are still common in some waters around the world, and the more severe thing is some of the crewmembers discharge untreated sewage deliberately in port or some waters where discharging sewage is not allowed.

Table 3: the number of deficiencies about implementation of the annex IV and the percentage of total number of deficiencies

time	number	% of total
2007	118	0.14%
2008	340	0.37%
2009	727	0.82%
2010	879	0.95%
2011	996	0.94%
2012	1013	0.99%
2013	1070	1.10%
2014	1199	1.32%
2015	1301	1.53%

Source: compiled by author based on the information from Tokyo memo's website

Table 4: the number of cases of illegal discharge of ship sewage and the total amount of fines in Shanghai port

time	number	total
2007	20	434000
2008	54	1165000
2009	58	1278000
2010	48	1091000
2011	56	1360000
2012	68	1411000
2013	85	1883000
2014	91	3548100
2015	117	4590000

Source: compiled by author based on annual report of administrative penalty

The IMO has attached more and more importance to the marine pollution caused by ship sewage in recent years, and has taken some practical and effective measures to strengthen the implementation of annex four. On the one hand, the IMO has granted more stringent inspection rights to the port states, and the main purpose of which is to urge the ships to dispose and discharge the sewage in strict accordance with the regulations. According to the relevant statistics from the Tokyo memorandum, the number of deficiencies found in PSC inspections about implementation of the annex IV increased year by year. Similarly, taking Shanghai (the largest port in China) for example, both the number of cases about illegal discharge ship sewage and the total amount of the fines gradually increased in the last decade, all of which shows that the

inspection of ship sewage is becoming more and more strict. The relevant data is shown in the table 3 and table 4.

On the other hand, the IMO has established special area to limit the illegal discharge of ship sewage. It is generally known that there is no special area for ship sewage at the beginning of formulation of annex IV, but the Baltic Sea has become special area at MEPC 62 in July 2011. New discharge requirements for passenger ships was given out while in this area, and it is very likely that more and more special areas will be established around the world in the future. In addition, some developed countries began to develop domestic laws to regulate the disposal and discharge of ship sewage, which was more strict than the international conventions, and the most important is that the IMO has also gradually accepted the practice in developed countries.

Generally speaking, along with the social public marine environmental protection consciousness strengthens gradually, the problems in the implementation of the annex IV gradually exposed in recent years. Consequently, IMO and some developed countries are trying to amend the annex IV of MARPOL convention by adding more stringent provisions, and this kind of practice is the trend of the times and it is irreversible. Everyone can imagine it is certain that the new amendments will supplement or replace the current provisions in the annex IV of MARPOL convention.

4.2 Reasons for illegal discharge of sewage

Nowadays, the sewage system or treatment plant on different vessels varies widely, and the working principle of the different equipment is not the same. Moreover, due to the difference of personal qualities and sense of responsibility, the working

performance of crew members differs from one another. Besides that, the standard and the degree of strictness of PSC inspections differ greatly in different contracting states, especially some developed countries have formulated domestic laws which are more strict than MARPOL convention, and the vessels arriving at these countries must comply with their domestic laws. Consequently, there is a variety of reasons for illegal disposal or discharge of ship sewage, including the direct and indirect reasons. In the following section, taking the example of the most popular sewage treatment plant on board—the activated sludge sewage treatment plant, the possible reasons which cause illegal discharge of untreated sewage are as follows.

4.2.1 The direct reasons

4.2.1.1 Crewmembers are not familiar with the working principle

In normal circumstances, the sewage treatment plant shall be managed and maintained by specific personnel from the department of engine. However, sometimes, these specific personnel are not familiar with the working principle of treatment plant, which often causes the plant to be used incorrectly. In this condition, frequently, the ship sewage is discharged into ocean directly without full disposal or adequate treatment.

The activated sludge sewage treatment plant is composed of aeration tank, sedimentation tank, disinfection room, air blower and overboard discharge pump. “Generally, the sewage is pumped into the aeration tank primarily; air blower inputs the fresh air to sewage and makes the sewage intermix adequately with the activated sludge. The organic matters in sewage is decomposed and transformed into inorganic substance by means of the biochemical reaction, such as carbon dioxide and water,

and then the activated sludge is flowed into sedimentation tank with sewage and deposited the bottom of sedimentation tank. Subsequently, the activated sludge is sent into aeration tank by means of return pipe and the clarified sewage is flowed into disinfection room via the overflow pipe. After disinfecting and sterilizing, the treated sewage is pumped overboard by discharge pump. (Shen, 2015, p.3)" The flow chart is shown in figure 8.

The activated sludge sewage treatment plant must be kept running continuously. Properly speaking, it is the air blower that shall be kept working; otherwise, the activated sludge will be dead or invalid due to the lack of oxygen; therefore the crew members must keep the button of air blower be switch on when the sewage treatment plant is in working condition. However, in practice, so many crew members don't know the working principle. Sometimes the engineers keep the air blower working intermittently, even switch off the button all the time, which will lead the activated sludge to lose activity. If so, even the treatment plant is in working condition, the sewage cannot be treated effectively.

Besides that, there are a few valves in the whole system. When the treatment plant is in normal working condition, only the valve of aeration tank is open, the valves of sedimentation tank and disinfection room must be closed at the same time. If these valves are also open, the untreated sewage will flow directly into the discharge pump. If so, some untreated sewage will be discharged overboard with the treated sewage, which will still cause the pollution of marine environment.

4.2.1.2 Sewage treatment plant is lack of maintenance

In general, there should be specialized personnel to manage the treatment plant on

board. In most cases, the specialized personnel are the fourth engineers, who will keep the treatment plant in good condition at any time. The fourth engineers shall carry out necessary maintenance, which is conducive to reduce the occurrence of faults. However, in reality, the treatment plant keeps running all year round; very few of fourth engineers carry out effective maintenance to treatment plants. If the treatment plant is lack of maintenance, various kinds of malfunctions happen frequently, which will cause the untreated sewage to be discharged overboard (Zhao, 2008, p. 31).

Figure 10: rust status of the aeration tank
Source: photographed by author in 2013

Figure 11: rust status of dosage tube
Source: photographed by author in 2013

Of course, some fourth engineers have a strong sense of responsibility, and they are willing to carry out maintenance. However, because the treatment plant is closed equipment, it is difficult for the fourth engineers to see the internal structure of the plants. Therefore, the major maintenance is only the appearance check in most cases. Actually, the examination of internal structure is much more important than appearance check, especially the inner pipeline. This is due to the fact that the inner pipe of treatment plant is easy to get serious rust under the corrosive action of sewage, if rust holes exist in the inner tube of air blower, the fresh air will not be

transported into the sewage, which will lead activated sludge to become void and inactivity (Wei, 2013, p.37). Besides that, the dosage tube is also very easy to rust; if the rust cannot be removed in time, they will stop the disinfection tablets from entering into the disinfection room, which will greatly reduce the processing effect of treatment plant. Some pictures are shown in figure 10 and figure 11.

4.2.1.3 Some provisions in MARPOL convention are not properly understood

There are clear regulations for discharging and disposal of ship sewage in the annex IV of MARPOL convention, and most of regulations are easy to understand. If the crew members dispose the ship sewage in accordance with these regulations, it can significantly reduce or avoid the pollution of the marine environment. However, some provisions in the annex IV of MARPOL convention are not properly understood by crew members, which is very likely to lead the untreated sewage to be discharged illegally.

In these regulations, the definition of "the nearest land" is the most likely to be understood improperly. As shown in figure 12, according to the written definition of "the nearest land" in MARPOL convention, "the term 'from the nearest land' means from the baseline from the territorial sea of the territory in question is established in accordance with international law" (International Convention for the Prevention of Pollution from Ships, 1973). Actually, in other words, the nearest land is a virtual line, not an idea of the nearest land or shore in geographical sense. However, in practice, so many crew members misunderstand the notion of the nearest land; they tend to think "the nearest land" is the nearest shore, reef or island. In that case, the untreated sewage is very likely to be discharged in a country's internal waters or territorial waters (Guo, 2014, p.35).

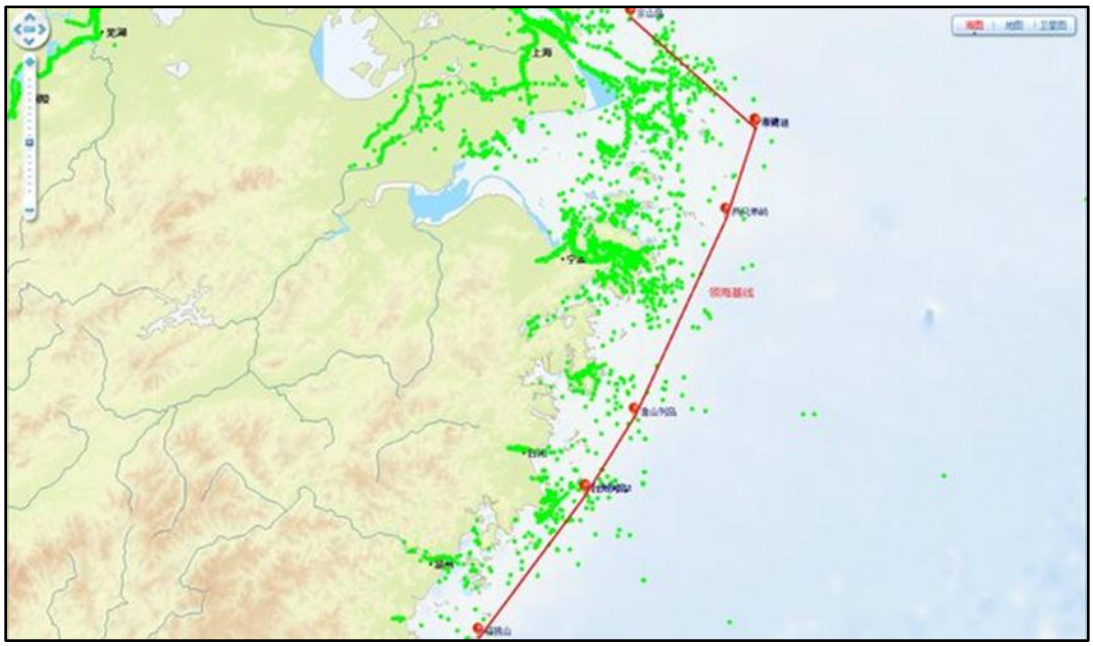


Figure 12: the baseline of territorial sea off the coast of China

Source: downloaded from Baidu.com

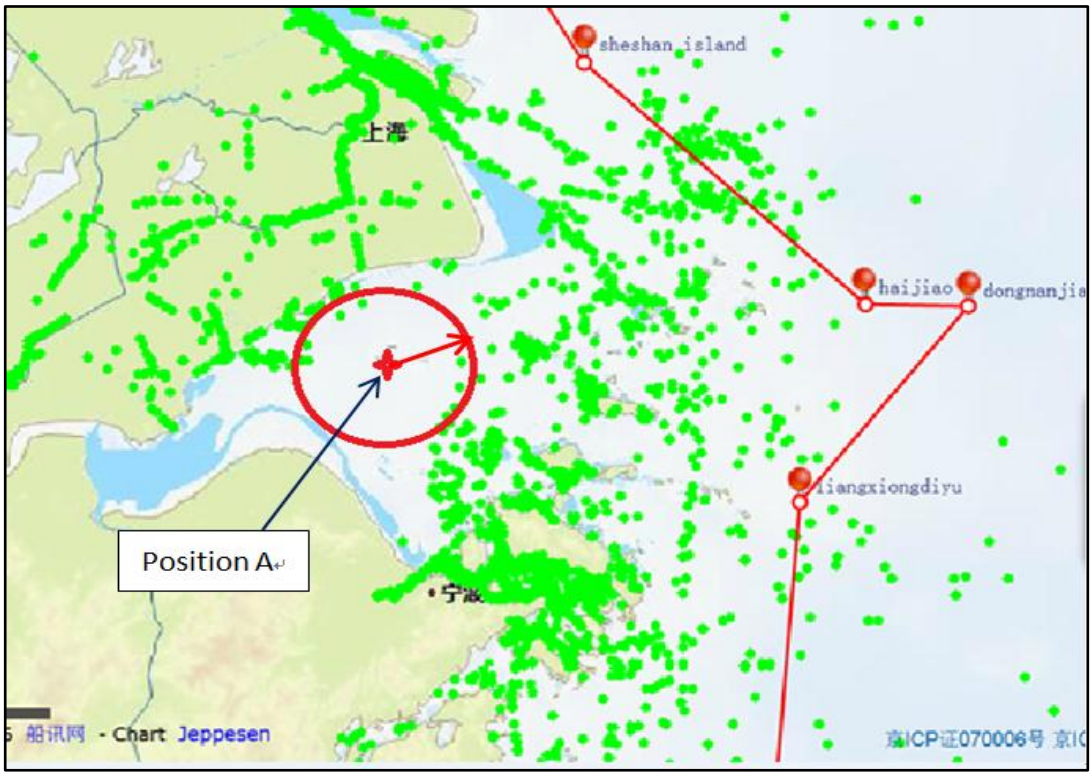


Figure 13: The baseline of the territorial sea outside the port of Shanghai

Source: compiled by author based on the picture obtained from www.shipxy.com

As seen in the figure 13, if the crew members discharge the ship sewage at position A, which is the center of the circle with a radius of 12 nautical miles, and the red line is the baseline of the territorial sea outside the port of Shanghai. According to relevant provision of annex IV, it is allowed to discharge the untreated sewage at a distance of more than 12 nautical miles from the nearest land. Although the position A is more than 12 nautical miles from the nearest shore, reef or island, the position A is at the inner side of the baseline of territorial sea. In fact, position A is located in internal waters of China. Obviously, it is illegal to discharge untreated sewage at position A.

4.2.1.4 Ships have no the discharge rate table for sewage, or the crew members fail to discharge sewage according to the requirements of discharge rate table

According to the relevant provisions of the MARPOL convention, the untreated sewage stored in holding tank should not be discharged instantaneously, “but at a moderate rate of discharge when the ship is en route and proceeding at a speed not less than 4 knots, while the rate should be approved by the administration based upon standards developed by the organization” (IMO, 2006). However, this standard does not incorporate the dilution of sewage with water or grey-water into calculations of the discharge rate. Therefore, “the rate is a conservative estimate and it is recognized that discharges of sewage in accordance with this standard will present a higher level of protection to the marine environment due to mixing prior to the actual discharge in addition to the mixing action of the ship’s wake”(MEPC.157-55, 2006).

If the holding tank for untreated sewage is available for sea-going vessel, there should be a discharge rate table on board, and the crew members responsible for sewage operations should dispose the untreated sewage according to the requirements of the discharge rate table. However, in practice, owing to negligence

of the standards and regulations adopted by IMO, ships often do not have the discharge rate table for untreated sewage. Even though the discharge rate table is available on board, the crew members confess hardly to discharge the untreated sewage in accordance with the requirements of table. In other words, due to the difficulty of being found or detected, untreated sewage stored in holding tank was discharged instantaneously in most of the cases, which obviously violates or deviates from the regulations and requirements of MARPOL convention.

Table5: sample form of the table of discharge rate

DISCHARGE RATE (m^3/h)					
SPEED (kt)	4	6	8	10	12
DRAFT (m)					
5	4.63	6.94	9.26	11.57	13.89
6	5.56	8.33	11.11	13.89	16.67
7	6.48	9.72	12.96	16.20	19.45
8	7.41	11.11	14.82	18.52	22.22
9	8.33	12.50	16.67	20.83	25.00

Source: obtained from resolution MEPC.157-55

4.2.2 The indirect reasons

4.2.2.1 Effective date of the annex IV is too late

It is well known that there are six annexes in MARPOL convention, whose effective date is very different. The effective date of the annex IV is later than other annexes except the annex VI, in particular, compared to annex I, that entered into force on 2 October 1983, and it was more than 30 years from the effective date up to now; almost all aspects of the annex I have been well implemented on board, as well as in shipping companies. Meanwhile, the crew members and shipping companies have adopted and accepted the requirement of annex I. However, the annex IV took effect on 27 September 2003, and the effective period is just only more than a decade. Up

to now, a great number of crew members and managers in company have not been adapted or accustomed completely the regulations and requirements of the annex IV. As a result, the probability of making a mistake or misoperation in the discharge of untreated sewage is very high, and the illegal discharge of sewage is still relatively common in reality.

4.2.2.2 Sewage pollution has received little attention

As we all know, the six annexes of MARPOL convention were related to six kinds of pollutants, and the order of the effective date reflects the different degree of attention from the social mass. In general, the earlier the annex comes into force, the greater harmful of the pollutants involved in the annex. Sometimes, some pollutants are very harmful to marine environment, but it is late when people realized the damage of them, such as ship sewage, marine exhaust gas.

Nowadays, many people have realized that the ship sewage has a great damage to the marine environment, but it is widely believed that sewage pollution is far less than oils pollution to marine environment. Consequently, ships and shipping companies fail to attach the same importance to sewage as oils and toxic substance. From the actual situation, compared with oils, explosive materials, noxious and harmful substances, the degree of attention from vessels and port state control, as well as the shipping companies and contracting government is far from enough.

4.2.2.3 PSC inspections are not strict enough

Due to a lack of enough attention and research previously, the problem of marine pollution caused by ship sewage is becoming more and more serious, and people are

paying more and more attention to this problem. However, compared with oils and harmful substances, the degree of concern is still not enough. Currently, so many inspections are carried out on ships, such as PSC inspection and pollution prevention inspection and so on, but these inspections related to ship sewage are not strict enough. The inspectors often only carry out inspections on the certificate and the appearance of the sewage treatment plant, which is very difficult to find illegal action on discharging untreated sewage.

In addition, the present PSC inspection procedure is flawed, which is not good for detecting the illegal discharge sewage timely. According to present PSC inspection procedure, the PSCO shall first check overall condition of ship, then go to the captain’s cabin or meeting room to carry out the inspections about the relevant ship's certificates and documents. If there are clear grounds in the initial inspection, a detailed inspection is necessary. Actually, sewage treatment plants are closed on some ships when the ships are in the period of the mooring at berths, and the untreated sewage is discharged into port waters directly. If PSCO comes on board to conduct inspection, due to the fact that usually the inspectors do not first go to the engine room to carry out inspection, there is enough time to destroy the evidence of illegal discharge of sewage and open the treatment plant for the crew members who are responsible for managing and operating of the plants. Owing to the defect of the procedure of PSC inspection, it is very difficult to detect the case of illegal discharge sewage on board for PSC inspectors.

4.2.2.4 Reception facilities at ports and terminals are not perfect

According to regulation 12 of annex IV of MARPOL convention, every contracting government shall ensure that ports and terminal provide adequate reception facilities

for reception of sewage to meet the needs of the ships using them, without causing delay to ships. However, the number of reception facilities is not enough in practice, in particular in the undeveloped and developing countries, the problem is more obvious and prominent. In most ports and terminals, few of companies or ships may provide the service of sewage reception, which lead to many ships have to discharge untreated sewage into ocean directly.

Currently, it is common that the urban domestic sewage cannot be treated or disposed in many undeveloped countries, let alone the ship sewage. Even if there are some companies and harbor boats engaged in ship sewage reception, due to lacking of effective supervision from competent authority and government, the most sad thing is that the receiving companies or the receiving boats are very likely to discharge the received sewage into port water area once again after receiving the untreated sewage, instead of transferring the received sewage to designated place to dispose by specific companies. This is another important reason for the large amount of untreated ship sewage being discharged into port waters.

4.3 Chapter summary

To summarize, compared with oils and toxic substance, the marine pollution caused by ship sewage is not so quick and unsightly, but sewage still has a great damage to the marine environment, and people did not pay enough attention to it in the past. Therefore, due to various reasons in the above discussion, the implementation of the annex IV of MARPOL convention is not ideal and unsatisfactory, and a large amount of raw sewage is discharged into port waters or ocean in the world every year.

Urban domestic sewage cannot be effectively treated in some countries, especially in

undeveloped countries and developing countries, not to mention the ship sewage. At the same time, some poor shipping countries have not joined and recognized the MARPOL convention, let alone to make their own laws and regulations. Consequently, due to the lack of effective supervision, besides the ships engaged in international voyage, so many coastal vessels and river vessels discharge untreated sewage into ocean directly, and the marine environment of the port waters is gradually deteriorating.

Fortunately, The IMO has attached more and more importance to this problem in recent years, and the establishment of special region of Baltic Sea in 2011 is an obvious sign. Besides, many port states have also increased the intensity and strictness of the PSC inspection recently. Meanwhile, they also did their best to improve the reception facilities at ports and terminals, all of which help to prevent the pollution caused by sewage.

Chapter 5: Procedure and main points of PSC inspection

5.1 Current procedure of PSC inspection

According to IMO resolution A.787 (19), port states shall carry out PSC inspection in accordance with the predetermined procedures, and the PSC officers must accomplish the initial inspection before a detailed inspection. In general, the officers begin initial inspection before embarking on a ship, mainly the general appearance inspection of the ship and the PSC historical records inspection, which can help the officers to learn about the overall condition of the ship. Besides that, the initial inspection also covers the ship certificates and documents, mainly the validity of the certificates and the normativity of the documents.

If the above mentioned items are very good, the inspection is over and the ship is allowed to continue its voyage. However, if the PSC officers find that the ship lack certificates or the certificates are not valid; perhaps after general inspection, they consider that there are clear grounds for believing that the ship does not substantially comply with the relevant provisions and requirements of the safety of ships or the prevention of pollution, then the PSC officers have the right to carry out a detailed inspection. After the detailed inspection, if they find that one or more serious deficiencies exist on the ship and the ship is regarded as a substandard ship, the PSC officers have good reasons to detain the ship.

Obviously, the above mentioned procedure is not perfect. After embarkation, the PSC officers have to firstly spend a great deal of time and effort on checking the certificates and documents. It is very difficult to find the ship’s illegal action and deficiency for the PSC officers, because during this period, the crew members have

enough time to destroy and hide the evidence and fact of illegal operation or unlawful act. For example, the crew member discharge the untreated sewage into port water directly, when the PSC officers are checking the certificates and documents after embarkation, the crew members have enough time to switch on the power of sewage treatment plant. If so, the PSC officers could hardly find the previous illegal discharge action when they inspect the sewage treatment plant. Of course, if the PSC officers suspect discharging sewage illegally exists on board, they may take a sample and test to ascertain whether the sewage meets the discharge requirements of convention, but the procedure of sample is so complex that almost no one would like to do it. In addition, the period of test is too long, it will take four or five days at least to await the test report in normal condition. If the officers detain the ship according to the test result, it often causes undue delay to the ship.

Consequently, the PSC inspection procedure should be changed slightly in my opinion. After embarkation, the PSC officers first go to engine room to check the sewage treatment plant and oil-water separator roughly, and then get into captain's cabin to check the certificates and documents. If two officers embark ship to carry out inspection, one of them goes to captain's cabin and another gets into engine room to check the pollution prevention equipment. If so, the PSC officers often can obtain the direct evidence of illegal discharge of ship's pollutants.

5.2 The main points of PSC inspection

5.2.1 Initial overall condition check

Normally, the PSC inspection is performed by two officers. As mentioned above, in order to obtain the direct evidence of illegal discharge of ship's pollutant, after

boarding ship, the two inspectors should follow two routes to carry out inspection. When one officer enters captain's cabin to check the ship certificates and documents, another officer should get into engine room quickly to inspect the ship sewage treatment plant immediately.

Generally speaking, this kind of inspection is mainly initial overall condition check. After getting down engine room, the PSC officer should firstly find the location of sewage treatment plant and check whether the sewage treatment plant is working or not at present. If the treatment plant is not running, the officer should use a camera to take a picture or video as evidence immediately, and then ask the engineers whether the ship has a sewage holding tank. If not, the fact is existing that the ship discharges the untreated sewage into harbor waters; if the engineers answer yes, the officer should go to captain's cabin to examine the sewage certificate to confirm whether there is a holding tank recorded in the ISPP certificate.

5.2.2 Change-over valve inspection

At present, there is a change-over valve on the sewage pipeline in most of ships, whose main function is to control the flow direction of untreated sewage. The untreated sewage can be fed into treatment plant or holding tank, and can also be flowed overboard through the change-over valve. The schematic diagram is shown in figure 14. In general, the change-over valve is located on the pipeline near the treatment plant or holding tank, and the main goal is to facilitate the conversion operations of sewage for the crewmembers.

After inspection of sewage treatment plant, the PSC officer should go to search the change-over valve on the sewage pipeline at first time, and check the change-over

valve's working position to ascertain whether the untreated sewage is flowing into the sewage treatment plant or holding tank. If not, it is obvious that the crew members directly discharge the untreated sewage overboard deliberately. One thing to note is that it is very quick to switch the change-over valve. Therefore, the PSC officer should find the change-over valve as soon as possible before the crew member switches on/off it. In practice, some ships discharge untreated sewage overboard through change-over valve in port waters, and they carry out the conversion operation only when they see the PSC officers boarding ship. If they accomplish the conversion operation before the PSC officer finds the change-over valve, it is very difficult to find the evidence of illegal discharge of untreated sewage for the PSC officer.

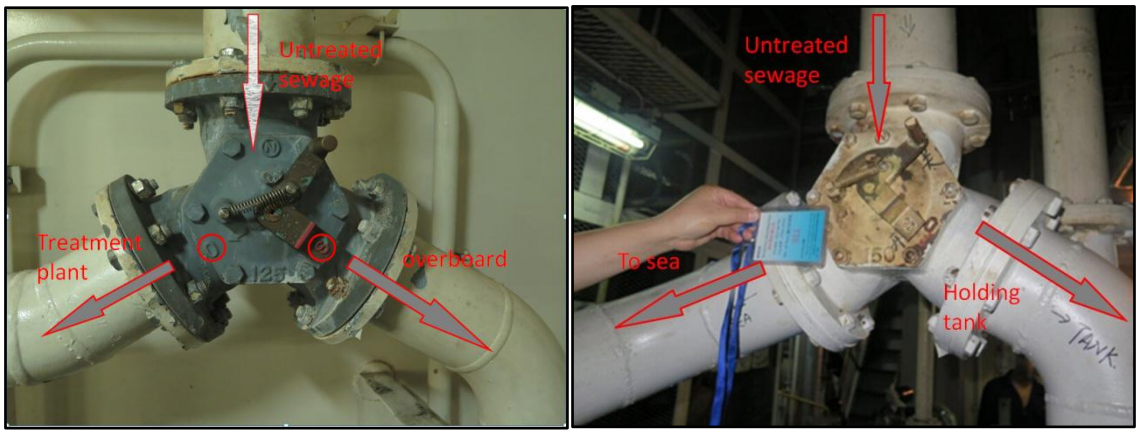


Figure 14: the change-over valve on the sewage pipeline

Source: compiled by author based on the pictures taken by the author in 2014

5.2.3 Air blower inspection

According to the introduction and discussion in 3.3.4.1, fresh air needs to be sent into the aeration tank persistently, and the main purpose is to keep the activity of sludge in the aeration tank. Actually, the bacteria in activated sludge are aerobic, and they

need the fresh air to keep activity. If fresh air is stopped, the bacteria will lose their activity and die. Therefore, when the sewage treatment plant is running, the button of blower must be in the state of opening.

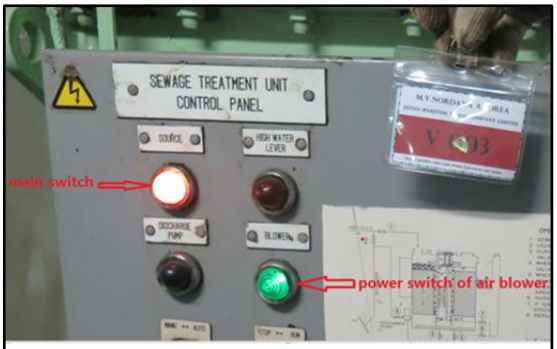


Figure15: the indicating lamp of air blower

Source: compiled by author based on the picture taken by author in 2014

Figure 16: the control panel of treatment plant

Source: compiled by author based on the picture taken

Figure17: the pressure gauge of air blower

Source: photographed by author in 2014

As shown in figure 15, there are several indicating lamps on the control panel of sewage treatment plant, but only two indicating lamps are luminous under normal conditions: one is the main power, and another is the air blower. When inspecting the sewage treatment plant, the PSC officer should pay special attention to the air blower. As shown in figure 16, if the indicating lamp of air blower does not light up, which means the air blower is not working. In such case, it is almost impossible that the ship sewage is treated or disposed effectively by the

sewage treatment plant.

Besides the indicating lamp, the PSC officer also focuses his attention on the pressure gauge of air blower, and he should check the pressure gauge whether the air pressure is within normal limits. As shown in figure 17, if the air pressure is zero or below the specific figure when the air blower is working, which certifies the fresh air cannot be imported into sewage, and the aerobic bacteria in the activated sludge will lose its activity and die (Xv, 2010, P.49). Under these circumstances, it is almost a certainty that there are holes on the air pipeline; therefore, further inspection to the inner air pipeline is necessary.

5.2.4 Internal structure inspection

In most cases, the PSC officers only conduct external visual inspection to the sewage treatment plant, and they almost rarely pay their attention to the internal structure and pipeline (Wei, 2013, P.39). Because of the strong corrosiveness of untreated sewage, the internal metal structure and pipeline are easy to rust, especially the treatment plants which have not been changed or replaced after the installation. If the corrosion of internal structure is very serious, the processing capacity of the treatment plant will be greatly reduced, and even the treatment plant may be completely ineffective.

In practice, the crew members use the treatment plant every day, but they rarely care about the internal structure and pipeline, which often leads the crew members to ignore the chemical change in the internal structure. Admittedly, it hardly gets rust in the first few years after the installation, and paying special attention to the internal structure and pipeline is also unnecessary for the crewmembers. However, the subtle chemical change happens all the time and the rust of metal internal structure will

become more and more serious (shown in figure 18). As time passes slowly, the processing capacity and efficiency will also be gradually reduced (Wei, 2013, P.38).

Figure 18: the internal structure of treatment plant

Source: photographed by author in 2014

Figure19: the internal pipeline of treatment plant

Source: photographed by author in 2014

When the PSC officers check the sewage treatment plant, they may open the sealing cover to check the corrosion of the internal structure, particularly the fresh air tube connecting to the air blower, as shown in figure 19. If there are rust holes existing on the internal air tube, although the air blower is in working condition and air pressure is within normal limits, because of serious gas leakage from the rust holes, the aeration of raw sewage is not sufficient either, which will either lead to the sewage cannot be fully mixed with the activated sludge. Meanwhile, the aerobic bacteria in activated sludge will also lose activity and die.

5.2.5 Checking the disinfection tablet and tube size

According to the introduction in 3.3.4.1, it is well-known that the treated sewage needs to be disinfected before discharging overboard, and the international common practice is that the crew members artificially put the tablets in sewage to disinfect

currently. In normal condition, the disinfection tablets are fed into sewage through a tube whose end connects a metal filter screen, and the filter screen is immersed in sewage. Usually, the disinfection tablets are overlapped on filter screen in the tube one by one. After the nethermost tablet dissolves, the upper tablet falls down on the filter screen under gravity effect (shown in figure 20), which effectively ensures that the sewage can be automatically disinfected.

Figure 20: the disinfecting tube of treatment plant.
Source: photographed by author in 2013.

Figure 21: the disinfecting tube blocked by rust.
Source: photographed by author in 2013.

The engine room is usually a muggy and humid environment, so the bare metal parts are very easy to rust in such damp conditions. In general, the outer surface of the disinfecting tube is coated with paint, but the inner surface is exposed to the humid air, as well as the difficulty in maintenance, the disinfecting tube is usually blocked because of the rust on the tube inner wall (illustrated in figure 21). When the PSC officers carry out inspection to the sewage treatment plant, they should pay special attention to the disinfecting tube, open the lid and check the rust condition of the tube inner wall. If what they see in the inspection looks like figure 21, it is definitely certain that the disinfecting tube is blocked by rust, which means that the disinfection tablets cannot be fed into sewage, and the sewage cannot be completely disinfected.

Besides that, the size of the disinfection tablets is another checking point for the PSC officers. Surely we all know that the diameter of the disinfecting tube is very different in variety of sewage treatment plants, and the size of disinfection tablets is also different in the market, and the various disinfecting tablets are shown in figure 22. Therefore, the shipping company should provide different sizes of disinfecting tablets in accordance with the diameters of the disinfecting tube.

Figure 22: the various disinfecting tablets

Source: photographed by author in 2013

However, as a matter of fact, some disinfection tablets are provided whose diameter does not accord with the size of the disinfecting tube in some ships. Sometimes, the crew members have to crush or smash the disinfection tablets, or the tablets could not be put into the tube; and sometimes the crew members put a number of tablets in the tube at the same time, which could cause the tablets to be stuck in the tube. If so, the disinfection tablets cannot contact with sewage in plant; in other words, the sewage discharged overboard is not disinfected.

5.2.6 Discharge record inspection

According to the relevant requirements of MARPOL convention, the untreated sewage stored in holding tanks shall be discharged into ocean in the light of the requirements of discharge rate table at waters away from the nearest land at least 12 nautical miles. Meanwhile, if possible, the relevant information should be recorded in special log book or engine log book, mainly the starting time and GPS position, the ending time and GPS position, as well as the depth and the ship's speed.

Figure 23: chart plotting of the discharge operation (A+B)

Source: compiled by author based on the picture taken by author in 2014

When the PSC officers inspect the discharge operation records, they may mark the discharge position and the baseline of territorial sea on nautical chart to check whether the discharge position meets the nearest distance requirement. Besides that, referring to discharge time recorded on engine logbook, GPS position and nautical chart data, the PSC officers can also check whether the discharge operation meets the requirements of discharge rate table.

As shown in figure 23 A, when the ship discharges untreated sewage into ocean, it is anchored in anchorage, not en route, so the discharge operation is not in accordance

with requirements of discharge rate table. In addition, the discharge position is located in waters inside of the territorial sea baseline; actually, the position is located in Chinese inland waters, so the discharge operation is illegal. Similarly, as shown in figure 23 B, the depth and the ship's speed meet requirements of discharge rate table, but the position is also located in Chinese inland waters, therefore, the discharge operation is also illegal.

5.2.7 Checking return pipe

In the activated sludge treatment plant, there is a special pipe between the aeration tank and sedimentation tank. It is the sludge return pipe, which is mainly used for the sludge backflow. When the sewage is discharged into sedimentation tank from aeration tank, some sludge is also discharged into the sedimentation tank with the sewage, and the sludge in the aeration tank will be less and less as time goes on, so the sludge need to be returned back to the aeration tank to ensure that the subsequent sewage can be treated effectively.

Figure 24: the return pipe illustrated by a torch

Source: photographed by author in 2013

Some lazy crew members sometimes throw pericarps, seed shells, tea-leaves and cigarette ends as well as other garbage into the toilet, which is very easy to cause the blocking of the return pipe. Once this pipe is blocked by garbage, which means the sewage treatment plant is in trouble and the raw sewage cannot be treated normally. Therefore, the PSC officers shall attach enough importance to this problem. In normal conditions, the return pipe is transparent rubber hose; when the hose is illuminated by a torch (as shown in figure 24), the PSC officers can check whether the liquid is flowing from sedimentation tank to aeration tank. If not, it is obvious that the return pipe is blocked by something, and the PSC officers shall inform the relevant crew member to carry out the clean-up action immediately (Xv, 2010, P.49).

5.2.8 Checking the crew member's practical operating ability

There are dozens of valves on the sewage treatment plant to control the flow direction of sewage (as shown in figure 25). When the treatment plant is running, some valves are open and others are closed. If one of the valves is in the wrong position, it means the sewage treatment plant is not operating properly.

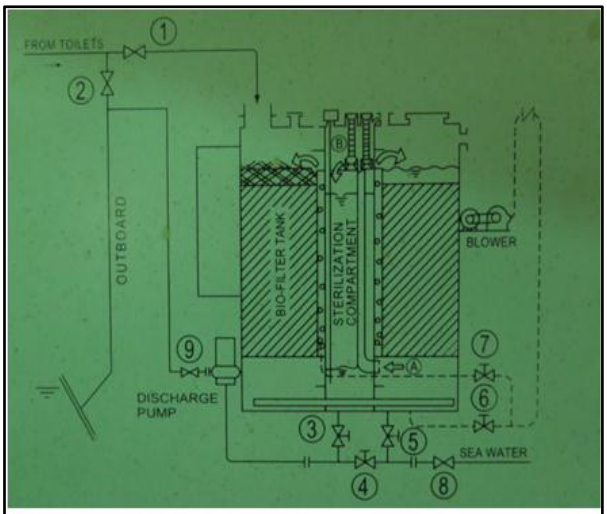


Figure 25: the valves of treatment plant

Source: photographed by author in 2013

Generally speaking, there is a schematic diagram of working principle pasted on the surface of sewage treatment plant, and the name and function of each valve are illustrated in the schematic diagram (shown in figure 26). The crew member who is

responsible for management of the plant shall be very familiar with daily operation of the plant. Besides that, there are also operating instructions pasted on the surface of sewage treatment plant (shown in figure 27), those who are not familiar with the treatment plant can also operate the treatment plant correctly according to the operating instructions.

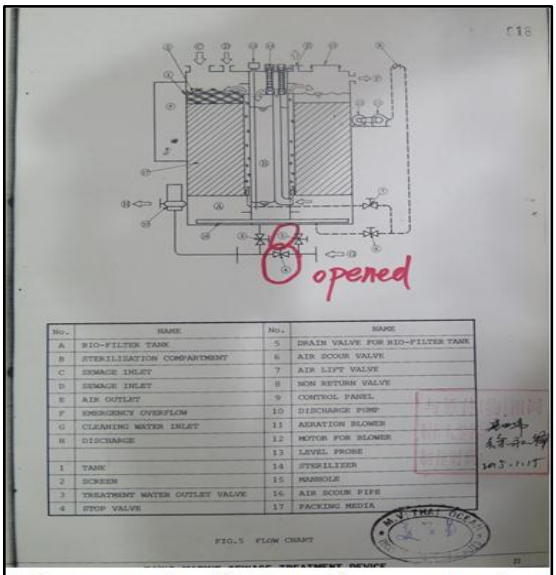
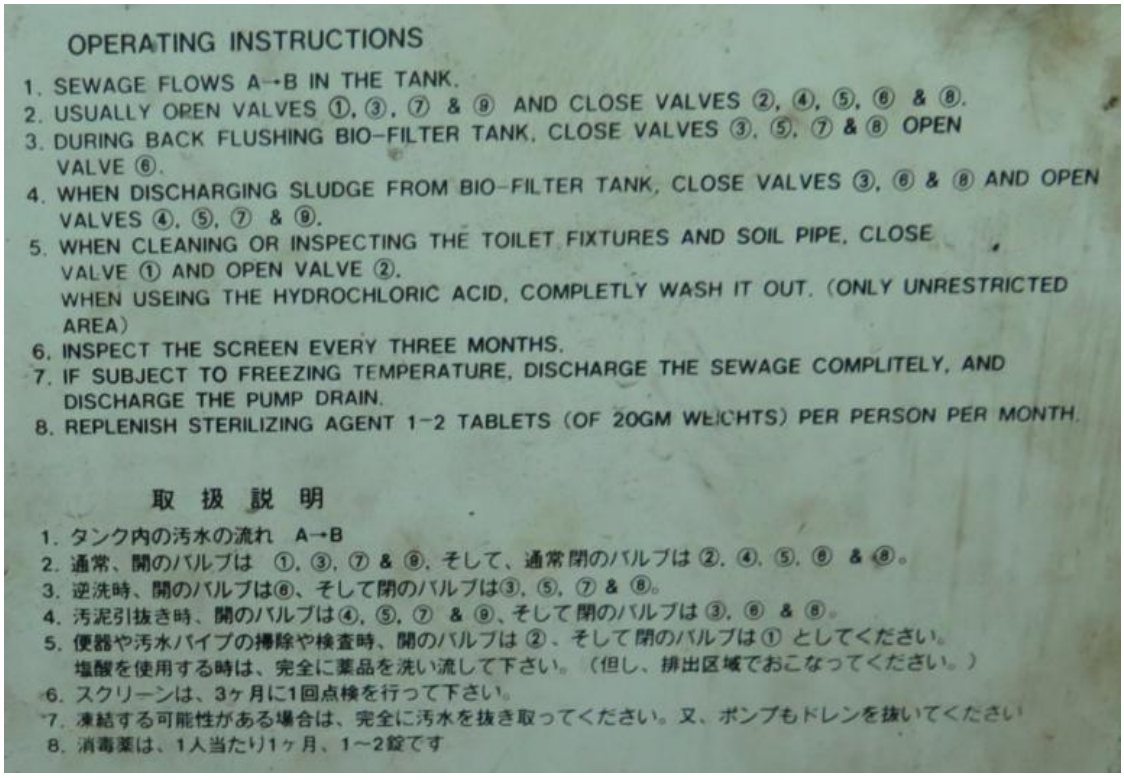


Figure 26: the diagram of treatment plant

Source: photographed by author in 2013



OPERATING INSTRUCTIONS

1. SEWAGE FLOWS A→B IN THE TANK.
2. USUALLY OPEN VALVES ①, ③, ⑦ & ⑨ AND CLOSE VALVES ②, ④, ⑤, ⑥ & ⑧.
3. DURING BACK FLUSHING BIO-FILTER TANK, CLOSE VALVES ③, ⑤, ⑦ & ⑧ OPEN VALVE ⑥.
4. WHEN DISCHARGING SLUDGE FROM BIO-FILTER TANK, CLOSE VALVES ③, ⑥ & ⑧ AND OPEN VALVES ④, ⑤, ⑦ & ⑨.
5. WHEN CLEANING OR INSPECTING THE TOILET FIXTURES AND SOIL PIPE, CLOSE VALVE ① AND OPEN VALVE ②.
   WHEN USEING THE HYDROCHLORIC ACID, COMPLETLY WASH IT OUT. (ONLY UNRESTRICTED AREA)
6. INSPECT THE SCREEN EVERY THREE MONTHS.
7. IF SUBJECT TO FREEZING TEMPERATURE, DISCHARGE THE SEWAGE COMPLITELY, AND DISCHARGE THE PUMP DRAIN.
8. REPLENISH STERILIZING AGENT 1-2 TABLETS (OF 20GM WEICHTS) PER PERSON PER MONTH.

取 扱 説 明

1. タンク内の汚水の流れ A→B
2. 通常、開のバルブは ①, ③, ⑦ & ⑨, そして、通常閉のバルブは ②, ④, ⑤, ⑥ & ⑧。
3. 逆洗時、開のバルブは⑥、そして閉のバルブは③, ⑤, ⑦ & ⑧。
4. 汚泥引抜き時、開のバルブは④, ⑤, ⑦ & ⑨、そして閉のバルブは ③, ⑥ & ⑧。
5. 便器や汚水パイプの掃除や検査時、開のバルブは ②、そして閉のバルブは ① としてください。
   塩酸を使用する時は、完全に薬品を洗い流して下さい。（但し、排出区域でおこなってください。）
6. スクリーンは、3ヶ月に1回点検を行って下さい。
7. 凍結する可能性がある場合は、完全に汚水を抜き取ってください。又、ポンプもドレンを抜いてください
8. 消毒薬は、1人当たり1ヶ月、1～2錠です

Figure 27: the operating instructions of sewage treatment plant

Source: photographed by author in 2014

Unfortunately, so many crew members who are responsible for management of treatment plant are not very familiar with the working principle, and some crew members cannot operate the equipment correctly even if they refer to the operating instructions. Therefore, checking the crewmembers' practical operative ability is very necessary.

When the PSC officers inspect the sewage treatment plant, they may ask crew members some questions about the routine working situation, such as the correct position of each valve, the frequency of use of disinfection tablets and so on. Additionally, as shown in figure 28, the PSC officers also ask the crew members to operate the sewage treatment plant by themself, such as testing the high and low level alarm of disinfection room, switching the change-over valve etc.

Figure 28: the inspection of operating ability
Source: photographed by author in 2013

5.2.9 Checking the holding tank

In order to meet the general requirements of the MARPOL convention and the local regulations of different countries in the world, at present, some seagoing ships engaged in international voyages have the "double insurance". In other words, they not only have the sewage treatment plant but also the holding tank. It is not allowed to discharge the sewage treated by treatment plant into port waters in some

developed countries. If the ship needs to stay at port a few days for loading and downloading cargo, it has to store the raw sewage in holding tank and discharge into the open sea after departure.

According to relevant requirements of regulation 9 of chapter 3 of annex IV, if the ship has a holding tank, the construction of holding tank shall satisfy the administration and shall have a means to indicate visually the amount of its contents. In most instances, as shown in figure 29, there is an indicator scale to display the liquid level on the exterior bulkhead of holding tank; even there is a high water level alarm on some ships. When the holding tank is full, the alarm will alert the crew members to discharge the sewage in time.

Figure29: the indicator scale of the holding tank

Source: photographed by author in 2014

In addition, when a ship stays in a port for a long time, it is very possible that the capacity of holding tank is insufficient. If the raw sewage is discharged into holding

tank continually, the untreated sewage will overflow to the bottom of engine room. In this case, some crew members often discharge the sewage into slop tank or special ballast tank to avoid the occurrence of overflow. If so, the ship will violate the relevant regulation of annex I of MARPOL convention, as well as relevant requirements of the BWM convention 2004.

5.3 Chapter summary

In conclusion，the author firstly points out the major drawback of the current PSC inspection, then discusses main points of PSC inspection about ship sewage in detail in this chapter. In fact, the types of inspection are not limited to PSC; the port states may also carry out pollution prevention inspection, so that the inspectors can circumvent the current inspection procedure.

As to the main points of inspection, because the working principle of activated sludge process is very similar to that of the membrane bioreactor, the main points of inspection are basically the same and the two systems are the most widely used on ships currently.

Of course, the main points of inspection include, but not limited to the contents of the above discussion, and the inspectors should first understand the working principle and accumulate work experience gradually in the actual work. If so, the inspectors can carry out a detailed and comprehensive inspection to the sewage treatment plant.

Chapter 6: Suggestions on strengthening management of ship sewage

Along with sea economy and shipping economy development, ships quantity increasing day by day. Due to the improper discharge of ship sewage, the pollution to the marine environment is becoming more and more serious in recent years. However, with the enhancement of public awareness of environmental protection, the pollution caused by the ship sewage to marine environment has recently received more and more attention. The marine environment pollution caused by ship sewage is a complex problem and involves the interests of many parties. In order to solve this problem, it needs the good cooperation and concerted effort from crew members, shipping companies, flag states and port states, as well as the IMO.

6.1 Crew members

6.1.1 Improving the professional quality by targeted training

In normal conditions, before embarking on a ship, the crew have been trained and obtained the certificate of competency, but it does not mean that the crew is very familiar with all kinds of equipment on the ship. Because there are a variety of equipment and instruments on board, the working principle and the daily operation condition are very different from each other; the crew must understand the working principle and keep the necessary maintenance to the equipment or instruments which are managed by them.

Almost all the equipment and instruments in engine room have the operating instructions for the crew members. However, some instructions are written in foreign languages, which are not the working language on the ship; so the crew members

may not be familiar with the languages and can't understand the specific content of instructions. Therefore, the professional quality of the crew is a key issue, and the professional quality of the crew decides whether they are suitable and qualified for their position. The targeted training is an effective way to improve the professional quality of the crew. Consequently, in addition to the general training, the crew should also receive targeted training, especially the practical skills training and English language training, which can improve the professional quality of the crew greatly.

6.1.2 Complying with conventions, laws and regulations consciously

There are definite rules about how to deal with the ship sewage in MARPOL convention, and some developed countries have enacted laws and regulations to restrict the deliberate discharge of sewage from ships in recent years, all of which shall be well implemented on all kinds of vessels. The crew members, whether they are working on a seagoing ship or an inland river vessel, should have a good sense of social responsibility, so they should be well aware of that protecting marine environment is the obligatory duty of every crew member (Li, 2008, p.37).

If discharging raw sewage illegally is found by competent authorities or PSC officers, the crew member will be severely punished. But it is very difficult to find illegal discharge of raw sewage in most of time. Therefore, it is very important that the crew members consciously follow the laws and regulations to dispose or discharge the raw sewage. In other words, the crew members shall consciously abide by the laws and regulations to dispose or discharge the raw sewage; it should not be the reasons of fear of punishment for illegal discharge of sewage，but because they want to protect the marine environment sincerely. If all the crew members can recognize this point, the pollution of marine environment will be eased and alleviated.

6.1.3 Strengthening the maintenance of sewage treatment plant

Almost all the equipment and devices on board need to be necessarily maintained after a period of time, otherwise they are likely to be damaged within a short time or the frequency of failure will be greatly increased. The sewage treatment plant is one kind of complicated equipment. Therefore the crew members should always check the operation condition and keep necessary maintenance in the daily use process, for example, the air pressure of blower, the inner pipeline and so on. Meanwhile, the crew members need to remove the rust of inner surface of disinfecting tube. Once the crew members find the damaged parts or other abnormal situation, they should immediately repair them or notify the shipping company to replace them to keep the treatment plant in good condition.

6.2 Shipping companies

6.2.1 Staffing qualified crew and equipping effective plant

The shipping companies purchase ships and employ crew members to carry out freight transportation at sea, so they should bear the ultimate responsibility for ship safety and pollution prevention. In daily operation, safety accident and pollution accident are the most anxiety of shipping companies. Once safety accidents or pollution accidents happen, the shipping company will be greatly affected, and may even face collapse.

Among all the factors affecting the ship safety, the ability and quality of crew member is the most important and critical factor. Therefore, the shipping company should staff qualified crew members for their ships. Besides that, the shipping

company should also equip with suitable and effective sewage treatment plants for the ships, as well as enough spare parts. If so, the suitable and effective treatment plants are operated and used by qualified crew members, and the situation of illegal discharge of untreated sewage can be effectively curbed.

6.2.2 Strengthening the training and assessment of the crew

Today is an era of information and knowledge explosion, especially science and technology develop rapidly in recent years, and new technology products and equipment are continually being applied to the ships. Even if the crew member holds the competency certificate before working on the ship, it is still very difficult to ensure that the crew member is competent throughout his career. As a result, the shipping company should constantly provide knowledge update training for the crew members at ordinary times. When new-style sewage treatment plant is applied to the ship or the crew member is not familiar with the daily operation of the plant, a targeted training is very necessary.

In addition, it’s not enough to just depend on training for the crew members. The shipping company should also carry out assessment to the crew members’ daily work performance, mainly check out their achievement, ability, attitudes and motivation in their jobs, and combine the assessment result with their salary, which is very helpful to improve the crew members’ subjective initiative. For example, the shipping company should check crew member’s operational ability of sewage treatment plant, daily round check and maintain, repair and cleaning frequency, operating record and so on. All in all, the shipping company should strengthen the assessment of the crew members, which will help them to do their job better.

6.2.3 Establishing internal quality management system and strictly implementing on the ships

Under normal conditions, nearly all large shipping companies established internal quality management system a few years ago, and the daily operation on the ships is in accordance with the requirements of the quality management system. The accident rate of the ships is obviously decreased, so the system plays a very important role in the management and operation of the ships. If all shipping companies are able to establish internal quality system and strictly implement on the ships; meanwhile, daily operation, management, maintenance and routine inspection of ship sewage treatment plant should be included in the quality system and form a closed loop management. In that case, the sewage treatment plant is properly used and the illegal discharge of the raw sewage will be greatly reduced.

6.3 Flag states

6.3.1 Strictly conducting the survey and certification

After the installation of the treatment plant and before the operation of the ship, the sewage treatment plant should be surveyed by the administration and obtain a certificate. When the validity of the certificate expires, the administration should also carry out a renewal survey to the treatment plant and issue a new certificate. In general, the survey and certification are conducted by the classification society in most countries. Of course; first of all, the classification society needs to be authorized by administration of flag state.

When the administration or the classification society carries out survey, the surveyors

should carefully examine the overall condition of the treatment plant and test whether the plant is in conformity with the requirements of the convention or domestic laws. In particular, when the surveyors carry out renewal survey, they cannot be judged only on the basis of the appearance of the treatment plant, but rather, they should pay close attention to the internal structure of the treatment plant, such as checking whether there are rust holes on the internal pipeline of air blower, the rust condition of disinfecting tube and so on. If there are defects affecting the normal operation of plant, the surveyors should inform the crew to rectify them, and then issue the new certificate (Xv, 2010, P.50). Besides that, the flag states should establish accountability mechanism. If the surveyors issue a certificate to a treatment plant which is obviously not in conformity with the requirements, that is to say, their survey is not in accordance with the relevant standards or there are other derelictions of duty, once it is discovered, the surveyors should be stopped to perform his duties permanently.

6.3.2 Strictly supervising the coastal vessels and the river vessels

In fact, besides the ships engaged in international voyages, there are a large number of coastal vessels and river vessels in most coastal states, and the number of these ships is much more than that of the ships engaged in international voyages. Generally speaking, these ships are not bound by the international conventions and lack the strict supervision of other the port states, so the flag states shall refer to the international conventions to make more rigid domestic laws and regulations to manage these ships.

According to the different characteristics of ship routes, the domestic laws should require these ships to equip different sewage systems. For example, the coastal

vessels always sail on the coastal waters and can dock at berth about a few days later; so these ships should equip a sewage treatment plant or comminuting and disinfecting system, and ship sewage may be discharged into ocean after being treated by treatment plant, or discharged into ocean after being comminuted or disinfected at waters away from nearest land 3 nautical miles at least. The river vessels only sail in the rivers and never go to high sea, so these vessels must have a holding tank with enough capacity. Meanwhile, the discharge pipeline should be sealed off by administration and used only in emergency. If the administration of flag state supervises the coastal vessels and the river vessels strictly, the illegal discharge of the raw sewage will also be greatly reduced.

6.4 Port states

6.4.1 Providing adequate reception facilities at ports or terminals

Based on the above discussion and introduction in 4.2.2.4, it is well known that one of important reasons for illegal discharge of raw sewage from ship is the lack the adequate reception facilities at ports or terminals. The port states should develop incentive measures to encourage relevant companies to set up more reception facilities in ports or terminals, and the charges should be reasonable and feasible, which is conducive to improve the ship’s initiative of discharging raw sewage into reception facilities.

Currently, because it is very convenient to send the sewage collected to sewage treatment works to dispose for the harbor boats, and the charge is lower than that of other reception facilities, it is very common that harbor boats are used as the reception facilities to collect the raw sewage in many ports. However, there is a

serious problem about the receiving ships. Due to lacking in effective supervision from administration, the receiving boats are very likely to discharge the collected sewage into port waters once again after receiving the untreated sewage, instead of transferring the untreated sewage to place designated or sewage treatment works. Therefore, the administration shall develop strict laws and regulations to supervise the receiving boats and ensure that the collected sewage cannot be discharge into port waters once again (Yuan, 2010, p.41).

6.4.2 Conducting strict inspection to the ships arriving at ports

If the untreated sewage is discharged into port waters, it will cause serious pollution to marine environment of port states, so the port states shall conduct strict inspection to the ships arriving at ports or terminals. Before embarking the ship, the officers should make a clear division of inspection, and one of the officers should go to engine room to check the sewage treatment plant firstly. When carrying out the inspection, besides checking the appearance of treatment plant, the officer should pay close attention to the internal structure, the disinfecting tube, the air pressure of blower, the operating ability of crew member, the discharge record and so on. If necessary, the officers may take a sample and test (Zheng, 2008, p.141).

6.4.3 Research and develop the rapid testing equipment

At present, the test of sewage will take a few days in normal conditions. After receiving the test report, if the officers detain the ship according to the test result, it often causes undue delay to the ship, so the officers are not willing to take a sample and test. The port state should organize relevant scientific and technical companies to research the rapid testing equipment. If this kind of equipment is invented in the near

future, the officers can test biological indicators of sewage rapidly using this kind equipment. Meanwhile, the officers can quickly judge whether the treated sewage meet the discharge requirements of convention. In that case, it can not only quickly determine whether the illegal discharge of sewage exist on the ship, but also avoid causing undue delay to the ship (Xv, 2010, P.50).

6.4.4 Making rigid laws to punish the illegal discharge

Once the ship is found to illegally discharge sewage into port waters, it is inevitable that the ship will be punished by port authority, but the seriousness of a punishment varies greatly in different countries. On the whole, compared with illegal discharge of oil, the punishment of sewage is significantly lower than that of oil. In order to protect marine environment genuinely, especially the port waters, the port states should make rigid laws to punish the illegal discharge of sewage. In addition to administrative fines, when necessary, the port states may also detain the ship, or notify the violation to the administration flag states of the ship, even may put the crew member responsible into prison when there are sufficient evidences to show that the ship discharge raw sewage into port waters maliciously.

6.5 The IMO

6.5.1 Comprehensively amending the annex IV

According to different actual conditions, each annex of MARPOL convention is constantly being revised in the follow-up assembly since its enactment, and the main purpose is make these annexes more adapted to the new circumstances and requirements, also in order to better protect marine environment. In most cases, only

a few provisions, regulations, or several chapters are revised by resolutions or protocols, and the whole annexes or conventions are amended by resolutions or amendments. For example, the annex V of MARPOL convention was amended by the resolution MEPC. 201(62) in July 15, 2011, and the entire contents of annex V was replaced by the new amendment, and entered into force in January 1, 2013.

However, generally speaking, both the content and the number are less than other annexes about the revision of the annex IV, and it was almost not modified since the effectiveness and implementation. Therefore, the IMO shall comprehensively amend the annex IV. The types of ship sewage should be extended firstly, and at least it should include bath water and kitchen wastewater. Secondly, discharge requirements should be more stringent, and the sewage shall not be allowed to discharge overboard in port waters, even if it is treated by plant. Thirdly, more special area or emission control area should be found to limit the arbitrary discharge of sewage around the world. In a word, it is time that the IMO initiates to develop a new annex to replace the existing annex IV.

6.5.2 Conducting the mandatory audit to all member states

As a professional organization concerned with the navigation safety and pollution prevention of ships, the IMO should do its utmost to urge and supervise all member states to fulfill their obligations. Voluntary IMO member states audit scheme have been practiced for several years, but there is still a gap between the current role and expectations, so the mandatory audit is necessary. Fortunately, the auditing mechanism of all IMO member states has been changed from voluntary audit to mandatory audit from 1 January 2016, which is helpful to ensure that the member states give full and complete effort to their obligations and responsibilities contained

in a number of IMO treaties. When carrying out the mandatory audit, the auditors should pay a close attention to the training of crew and PSC officers, domestic legislation and reception facilities at ports and so on. In brief; the mandatory audit can achieve harmonized and consistent global implementation of annex IV for all IMO member state.

6.5.3 Creating a blacklist system

The blacklist system is always a powerful measure to supervise individual and company to abide by the relevant laws and regulations, and there is no exception in the shipping industry. In order to supervise the ships and crew to dispose and discharge the ship sewage in strict accordance with conventions and laws, the IMO shall create a blacklist system: the ships of the deliberately discharge untreated sewage into port water should be included in the blacklist, and the IMO should regularly publish the blacklist to all member states. When the ship arrives at other ports, the PSC officers should pay close attention to the ship and carry out strict inspection. In that case, the ship would fall into trouble and inconvenience, which will compel the shipping company to strengthen the management of the ships and the training of crew members, so the blacklist system helps to reduce the illegal discharge of ship sewage.

6.6 Chapter summary

A large amount of untreated ship sewage is discharged into ocean every year; this situation is continuing, and the marine environment is deteriorating. Everyone should have a clear understanding of the current grim situation of marine pollution, and all the member states should make joint efforts or work together to stop and change the

terrible situation.

Five parties, the crew members, shipping companies, IMO, flag states and port states, can co-play a unique and important role in their respective fields. If crew members are qualified and competent, shipping companies have a sense of social responsibility, flag states and port states attach great importance to environmental protection, and the IMO develops more stringent discharge requirements, if there will be good cooperation and joint efforts among the five parties, this bad situation will be changed in the near future.

Chapter 7: conclusion

It is the consensus of most people that shipping is an important industry with very long history, and relevant documents show that shipping has been served all humanity for nearly 5000 years. Shipping can provide a significant service to almost everywhere on the global, and more than 90% of world freight is transported by ships. In most cases, if the shipping industry is well-developed in certain country, its economic development speed is relatively fast, and vice versa. In a word, shipping has made a great contribution to the development of the world economy, and will continue to make a greater contribution in the future.

However, along with the development of technology and the enhancement of people environmental protection awareness in recent years, as the old traditional industry, the shipping industry has once again received special attention from the public. People not only attach importance to the role of the shipping industry to the economy, but also pay attention to the serious pollution problem caused by it in the course of development.

At present, some significant changes are gradually taking place in this traditional field. On the one hand, the quantity of ships is getting more and more, and the trend of the large-size of ship is more and more obvious. On the other hand, more and more new technologies and equipment are being applied to the ships, and the requirements for ship safety and pollution prevention are getting higher and higher. In other words, the standards for the discharge of ship pollutants are getting higher. In brief, it is hoped that the ship will carry more cargoes in the case of the discharge of pollutants as little as possible.

Ship sewage, an important pollutant generated during the operation of the ship, has a great damage to the marine environment, even if the damage of sewage is not as serious as oils. Although there are clear requirements and regulations on the treatment and discharge of sewage for the international voyage ships in the convention, these ships still discharge the untreated sewage into the ocean, unwittingly or deliberately. More seriously, there are a large number of coastal vessels and river vessels, which are not bound by the international conventions and lack the supervision of the port states, so that the amount of sewage discharged by these ships is much more than that of the ships engaged in international voyages.

As for the sewage treatment systems, the comminuting and disinfecting system is relatively rare on ships, the holding tank is mainly used on river vessels and some coastal vessels, and the sewage treatment plant is widely used on ships engaged in international voyage. Currently, there is a variety of sewage treatment plant based on different working principles in the current market, and the membrane bioreactor has been more and more popular in recent years, but the activated sludge treatment plant still has the highest market share due to its outstanding overall performance.

Because the activated sludge treatment plant is very common on large-sized ships, the PSC officers or surveyors should understand its work principle and master the inspection methods. When carrying out the inspection, the officers should attempt a variety of inspection methods, not only check the appearance of treatment plant, but also focus attention to the internal structure. In addition, the officers may also check the discharge record or require the crew member to conduct the actual operation to verify his operating ability. If possible, sampling and testing is a good way.

On the one hand, there is no doubt that the shipping industry is a traditional industry

with a long history, and it has made a great contribution to the development of international trade and the world economy. At the same time, it is certain that the shipping industry will bring more or less pollution to the marine environment. On the other hand, the ocean is a common treasure of our human beings, and the protection of the marine environment is our humanity's common responsibilities. How to coordinate the relationship between the shipping industry and the marine environment is the problem that we should take into account at present.

If the crew, the shipping companies, the flag states, the port states and the IMO can fully perform their respective duties in their respective fields; meanwhile, they work together and collaborate with each other, the rapid development of shipping industry while maintaining a clean marine environment is no longer a distant dream for us human beings, in short, safer navigation, cleaner ocean and more efficient transportation.

References:

Analysis of how to strengthen the inspection of ship sewage pollution. (2016, January 29). www.Docin.com. Retrieved January 29 2016 from World Wide Web: http://www.docin.com/p-1443125221.html

Cai ji. (2015.April). Discussion on implementation of four Annex of MARPOL convention. *Navigation.* 2015(4), 68-72.

Cai jun & Huang rongfu & Chen yong. (2007, December). Application of MBR to domestic sewage aboard ship treatment. *Ship & Ocean Engineering*, 36(6), 110-112.

Cao haibin. (2007, September). Present situation and Prospect of modern ship domestic sewage treatment technology. *China Water Transport,* 7(9), 38-39

Chang Y CWang N & Durak O S. (2010) Ship recycling and marine pollution. *Marine Pollution Bulletin*, 60(9), 1390-1396.

Chen yunsheng. (2008, July). Discussion on the feasibility and necessity of charging the ship sewage. *Proceedings of the International Conference on the implementation of the International Convention for the prevention of pollution in ships, 2008*, 2008(7), 122-125.

Chen eryuan. (2005, May). All the previous amendments of annex IV of MARPOL73/78 and the relevant PSC inspection. *China Maritime Safety*, 2008(5), 40-43.

China Classification Society (2011). China. In Beijing publishing, *International Convention for the Prevention of Pollution from Ships, 1973 (consolidated edition 2011) (pp.236)*. Beijing: China Communication Press

Da jing. (2015. May). Introduction to vessel pollution way and present situation analysis. *World Shipping*. 2015(5), 53-55.

Discussion on how to carry out a PSC inspection to ship sewage treatment plant.

(2016, April 20). www.Docin.com.
Retrieved April 20 2016 from World Wide Web:
http://www.docin.com/p-1541512294.html

Dong liangfei. (2005, May). Study on Pollution Characteristics and countermeasures of sewage aboard ships. Unpublished doctor's thesis, Xi'an University of Architecture and Technology, Xi' an, China.

Fang yulin & Sun qun.(2010, January). How to understand the discharge requirement of Annex IV of MARPOL convention. *China Ship Survey*. 2010(1), 110-111+139.

Gui yonghui. (2014, February). Some ideas on the implementation of preventing the sewage pollution of coastal ships. *China Water Transport*, 14(2), 185-187.
Retrieved October 17 2015 from World Wide Web:
http://www.docin.com/p-1324801417.html.

Guo jiang. (2014.January). Legal Interpretation of discharge requirement of ship sewage. *World Shipping.* 2014(1), 34-36.

Guo jiang. (2014, June). Re-discussion on the lawful boundaries of ship's sewage discharge requirements. www.Docin.com.
Retrieved June 2014 from the World Wide Web:
http://www.doc88.com/p-8955504743898.html

Han lei. (2010, July). Analysis on how to strengthen the on-site supervision and inspection of the pollution of ship sewage. *Proceedings of the 2010 Annual Conference on marine pollution prevention*, 2010 (7), 414-417.

Hu zhiyue & Zhong dengming.(2014. December). Trends and Progress of Ship Sewage Treatment. *Journal of Chongqing University of Technology.* 28(12), 64-70.

Huang wen. (2012, June). Basic research on fast detection method of sewage aboard ships. Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Huang rong & Lin wei & Zhou jian. (2014, May). Study on marine sewage treatment techniques. *Mechanical and Electrical Equipment*, 2014(03), 59-61.

International Maritime Organization.(2011, November 30). *PROCEDURES FOR*

PORT STATE CONTROL, 2011. Resolution A.1052(27). London. Author

Jiang yanmin & Zhu minghe & Zheng daochang. (2011, October). Progress in Research on Treatment Technology of Shipping Sewage. *Journal of Ningbo University (NSEE)*, 24(4), 128-132

Jin jianzhong.(2011.July). Present situation of ship pollution and the prevention and control measures. *China Water Transport*. 2011(7), 20-21.

Jin weizhong. (2005, May). Research on Mechanism of Marine Membrane Bio-Reactor and its Sewage Treatment. Unpublished master's thesis, Suzhou University, Suzhou, China.

Jing wei. (2010, June). Research and Application of Optimum Selection Method of Ship Sewage Treatment System. Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Li yvle. (2010, April). Research on the marine sewage treatment plant based on Ultrafiltration Membrane technology. Unpublished master's thesis, JiMei University, Xiamen, China.

Li sen. (2010, June). Study on sewage from ships and control measures of preventing sewage pollution in China. *Journal of Dalian Maritime University,* 2010(S1), 99-101.

Li jianjun & Jiang guanghui & Xing zhe & Yv pengfei & Liu xiaolong. (2012, January). Current research status and development trend of ship sewage treatment technology. *Light Industry Science and Technology,* 2012(1), 88-90.

Li cairan & Liu feng & Ma li & Li xiangbo & Zhang shengtao & Xiang bin. (2014, March). Research on treatment of sewage from ships by Ti/IrO2-RuO2 electrode. *Technology of water treatment*, 40(3), 71-74.

Li zhongchen. (2008, June). Study on sewage treatment technology and sewage treatment system aboard ships selection. Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Li he. (2014, October). Analysis and control of illegal sewage of ship. Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Li jianqiang. (2008, December). Discussion on the present situation and Countermeasures of the pollution of ship sewage. *Pearl River Water Transport,* 2008(12), 35-37.

Lin jing & Di jinjiang & Chen yirui & Chen bo. (2016, February). Research on ship sewage water pollution prevention countermeasures. *China Maritime Safety,* 2016(2), 47-49.

Liu yuanyuan. (2013, June). Improved MBR treatment of sewage from ships Characteristics. Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Lv xiaoyan & Song ming. (2013, November). Statistic Analysis on Alleged Inadequacy Reports of GISIS Port Reception Facilities. *China Maritime Safety,* 2013(11), 49-52.

Mariani Ariffina & Siti Norhafizah & M Sulaimanb. (2015, October). Regulating sewage pollution of Malaysian rivers and its challenges. Procedia Environmental Sciences, 2015 (10), 168-173. Retrieved October 30 2015 from World Wide Web: http://creativecommons.org/licenses/by-nc-nd/4.0/

Mei Xiong &Yu Chengxiong. (2008, July).Discussion on the disposal methods of sewage from ships. *Proceedings of Pollution Prevention on Ship*. 2008(7), 74-77.

Meng zhengrong & Wang chenming. (2011, December). Current status and development trend of ship sewage treatment technology. *Transportation Enterprise Management*, 2011(12), 50-51.

Pan xiaofeng. (2009,December). The Implementation Measures of Annex IV of "MARPOL 73/78" Convention. *Shipping Management*, 2009(12), 21-24.

PSC Inspection of Ship Sewage Treatment Plant. (2015, October 15). www.Docin.com. Retrieved October 15 2015 from World Wide Web: http://www.docin.com/p-1322082606.html

Sheng weiqun & Deng lijuan & Liu lihong. (2016, January). Analysis of Status of International and National Ship Anti-Pollution Rules and Standards and Study of Countermeasures in China. *Ship Standardization Engineer,* 2016(1), 6-11.

Ship sewage water quality standards and the current status of maritime law

enforcement inspection. (February 28 2014). www.Docin.com. Retrieved February 28 2014 from World Wide Web: http://www.docin.com/p-771408919.html

Tian jinping. (2015, September). Study on progress and development trend of ship sewage treatment. *Science & Technology and Enterprises*, 2017(17), 98.

Tong xin & Wang zongtao. (2015, December). Simulating System Design for Marine Sewage Treatment Plant. *Journal of Shangdong Jiaotong University*, 23(4), 62-67.

Xu qian & Sunxu. (2015.February). Study of implanted sewage treatment plant based on the principle of anaerobic fermentation. *China Shiprepair.* 28(1), 25-29.

Xu qin & Fang zhaoqi. (2003, November). Pollution caused by ships and Countermeasures of marine environment. China Water Transport, 2003(11), 30-31. Retrieved November 2003 from the World Wide Web: http://www.docin.com/p-1099146987.html.

Xu bingxiang & Mao chensong & Xiang weidong. (2011, June). Current situation analysis and technical improvement of ship sewage treatment. *China Water Transport,* 2011(6), 18-19.

Xue qian & Sun xv & Zhu fan & Liu zhihong & Mao puxiu & Zheng weigang. (2015, March). Analysis of anaerobic fermentation sewage treatment plant. *Environmental Study and Monitoring,* 2015(1), 48-50.

Xue qian & Sun xu & Zhu fan & Liu zhihong & Zheng weigang. (2015, February). Study on the implanted sewage-treatment plant based on anaerobic fermentation. *China Ship Repair,* 2015(2), 25-29.

Xv zhongbing. (2008, March). Supervision and suggestion on prevention and control of ship sewage pollution. *Navigation,* 2008(3), 44-47. Retrieved July 13 2015 from World Wide Web: http://www.docin.com/p-1220435172.html

Xv Honger & He Jiangmin.(2010,January). Discussion on the ship's sewage pollution inspection. *China Maritime Safety*. 2010(1), 47-50.

Wang qi. (2012, December). Research on efficiency of membrane bioreactor for ship

domestic sewage treatment and membrane fouling mechanism. Unpublished master's thesis, Harbin Engineering University, Harbin, China.

Wang yong & Rui zhenfeng & Zhang zhiqiang. (2008, April). Marine environmental protection and vessel's marine pollution prevention. *World Shipping,* 31(2), 49-50. Retrieved November 2008 from the World Wide Web: http://wenku.baidu.com/view/43c5ad10a2161479171128f8.html

Wang xiaozhong. (2011, February). Discharge standard and treatment method of ship sewage. *Science & Technology Information*, 2011(2), 119-120. Retrieved February 2011 from the World Wide Web: http://www.cqvip.com/read/read.aspx?id=36778614

Wang xianhui & Gao xiaotao. (2011, July). Current status and problems sewage treatment of inland waterway vessels. *Enterprise Management,* 2011(7), 66-68. Retrieved July 24 2011 from World Wide Web: http://www.docin.com/p-235734291.html

Wang wei & Wang xinquan (2010, June). Analysis of marine sewage water management. *Journal of Dalian Maritime University,* 2010(S1), 92-95.

Wei huaxing & Zhang huanjie. (2014.December). The latest requirements and impact analysis of six Annex of MARPOL convention. *Shipbuilding Standardization & Quality.* 2014(6), 40-47.

Wei dong & Ge xiaofeng.(2013. December). Case study of a PSC inspection on ship sewage treatment plant. *World Shipping.* 36(12), 37-38+51.

Wei dong. (2013.November). Case study of a PSC inspection on ship sewage system. *China Maritime Safety.* 2013(11), 37-39.

Wu yvgen. (February 18 2016). Analysis on the installation of preventing sewage pollution system on small coastal ships. *ACADEMIC*, 2016(2), 48-49. Retrieved February 18 2014 from World Wide Web: http://www.docin.com/p-1460905545.html

Yaun peisheng & Bai zhengguang. (2010, December). The Development Trend of the New Treatment Technique of Ship's Sewage. *Ship & Ocean Engineering*, 2010(12), 41-43.

Yang zhou. (2014, November). Research on portable rapid detection system Pathogen in sewage form ships based on STM32. Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Zhang xianchao. (2011, June).Equipment Research of the Ship Sewage Treatment. Unpublished master's thesis, Anhui Engineering University, Wuhu, China.

Zhang wentao. (2014, December). MBR method treatment research of simulated ship sewage. Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Zhang yu. (2013, December). Discussion on the regulations of the prevention sewage pollution of domestic seagoing ships. *China Water Transport,* 2013(12), 61-62+140.

Zhang jianglong & Liu mengyun. (2015, September). Analysis of marine domestic sewage treatment technology. *China Water Transport,* 15(9), 154-156+179.

Zhao haijun. (2008.April). Annex IV of MARPOL convention and PSC inspection. *Tianjin Navigation,* 2008(4), 30-32.

Zheng jinming. (2010, June). Ship sewage treatment and PSC inspection. *Journal of Dalian Maritime University,* 2010(6), 96-98.
Retrieved May 12 2016 from World Wide Web:
http://www.docin.com/p-1451376319.html

Zheng junyi. (2008.January). Discussion on the PSC inspection about sewage treatment plant. *Transportation Science & Technology.* 226, 113-114.

Zhu linna & Liu hui & Ren zhijun & Zhang lin. (2010, October). Research progress of ship sewage treatment technology, *China Water Transport,* 2010(10), 14-15.