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Research on the ballast water management in Shenzhen Port waters : multiples proposals for prevention of invasive species

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RESEARCH ON THE BALLAST WATER MANAGEMENT IN SHENZHEN PORT WATERS: MULTIPLES PROPOSALS FOR PREVENTION OF INVASIVE SPECIES

By

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DECLARATION

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

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

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ABSTRACT

This paper aims to illustrate the ballast water manage issues in the Shenzhen Port waters at the condition that China government is not a contracting state of the International Ballast Water Management and Sediments Convention 2004. This convention provides guidelines on ballast water exchange standards, and encourages a more stringent approach too.

In this research paper, the methodology and materials use are given in the Chapter 1. It takes 3 months for collect and analysis 188 samples in the Shenzhen Port waters by categorized water geography source. Considering the previous studies on ballast water in Shenzhen Port waters is not strongly to support a perfect management system, the data of samplings are used for analysis of the current marine environment status in Shenzhen Port waters. The experimental data are listed in the Chapter 4 to help find the risk of water source. Combined with the vessel risk ranks downloaded from the Tokyo MOU computer, a new risk matrix can be developed which used to find the highest risk area in Shenzhen port waters. Also, understanding the different standards are introduced under the requirement of this convention, multiple ballast water treatment approaches are discussed in the chapter 3. Generally speaking, any kind of treatment both has its advantages and drawbacks. So how to supervise the vessel's discharge action will be a new problem faced in front of Shenzhen port authorities. Hence, proposals are made to encourage more practical approaches on remedying some of the weaknesses before China government ratify this convention. It is concluded that if the proposals may be considered seriously by the Shenzhen Port authorities by adopting additional regional legislation and policies to restrict the waters that not covered by the international convention, it would facilitate progress in dealing with ballast water treatment, specifically, the effort would improve the whole management level on the protection of marine environments in Shenzhen port waters.

Key words: Ballast water, Management, Proposals, Sampling, Risk, Assessment

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LIST OF ABBREVIATIONS

AGR	Apparent Growth Rate
ANS	Aquatic Nuisance Species
BWMB	Ballast Water Management Book
BWMC	International Ballast Water Management Convention 2004
BWMP	Ballast Water Management Plan
COD	Chemical Oxygen Demand
DBT	Double Ballast Tank
IMO	International Maritime Organization
DWT	Deadweight Tonnage
MEPC IMO	Marine Environment Protection Committee
MSA	Maritime Safety Administration
PSC	Port State Control
PSCO	Port State Control Officer
SPSS	Statistical Product and Service Solutions
Tokyo MOU	The Memorandum of Understanding on

	PSC in Asian-Pacific Region
VTS	Vessel Traffic Service
RO	Recognized Organization

Chapter1

Introduction

1.1 Purpose of Study

The damage to local marine environment brought by ballast water is mainly through the organisms by transferring pathogens, like Vibrio cholerae. Besides the ballast water in the ship's tankers, these harmful species also can be found in the sediments (Prange& Pereira, 2013, pp.127-134). For preventing the environment damage caused by ballast water and sediments, this paper examines the issue of invasion species in Shenzhen port waters introduction by the discharge of ballast water from vessels. Besides the technical aspects of ballast water management, samples collection in different vessels from various corners in the global location are analyzed for the purpose of good proposals sent to port stories.

This paper surveys existing countries and international actions to address the ballast water problems, and highlights the options for addressing this problem through practical, technical, and legal mechanisms. Considering the status of BWC 2004 in China, regulatory and non-regulatory actions are established by Shenzhen MSA in order to minimize or might minimize the spread of aquatic nuisance species. In the last part of this paper, it proposes recommendations on how to address the issue of preventing invasion species.

To achieve the aims of this paper, the following issues should be focused on:

1. Assessment on the ballast water discharges in the port of Shenzhen China in the prevailing level should be established for finding or identifying the approximate quantities and trends;
2. A sampling program, representing the source and quantities of ballast waters being discharged in the Port of Shenzhen, for evaluating the extent situation of invasion creatures should be researched by the governments departments;
3. The necessity of introduction of ballast water reporting system when vessels call to the Port of Shenzhen will be discussed;
4. How to set up risk assessment mechanism on ballast water management needs and prompt the future legislation.

1.2 Study methodology

Through literature analysis, this study investigates the actual situation of ballast water management behind the existing legal framework in Shenzhen waters. In qualitative research, the researcher visited the Shenzhen MSA and Shenzhen Entry-Exit Inspection and Quarantine Bureau personnel. To understand the local shipping industry in response to the requirement of BWMC, in-depth interviews was also conducted with captains in Shenzhen port. The data is origin from Shenzhen MSA (China) and reports handed by the ships to the Shenzhen Port. Those materials are collected for analyzing the ballast water management status in the period between February 2015 and April 2015 (IMO, 2004). Ships characteristics include full load capacity of DWT, GT and their ballast water tanks capacity are collected. In addition identify to the detail information about tanks that used for exchange ballast water before berthing Shenzhen port, the information about physic-chemical parameters of the ballast water are sent to the China ocean research institute for analyzing the specific weight, temperature, salinity, etc., The model proposed by Raikow is helpful for analysis (Raikow et al, 2007, pp.717-725). For geography information, this paper seeks help from the world wild web site: www.marinetraffic.com&www.earthpoint.com for the real path of reporting vessels.

Having considered that the average ship speed is underestimated, this paper uses the maximum time period for middle ocean exchange ballast water. Lastly, this paper also develops a number of special approaches for addressing ballast problem under international convention requirement by using the Shenzhen MSA's authority to review documents and evaluating ballast water reporting forms.

1.3 Literature review

As important parameters, the discharge volume sometimes is based on estimation. There are many methods on the calculation ballast water discharge volumes in local port waters in previous studies, for example, Suban endeavored to find the basic relationship between DWT and ballast capacity (Suban et al, 2006, pp. 69–75), and some models were even set up by different types of vessels. In recent studies, many authors have focused on the information from vessel reporting systems which was analyzed in the assessment of ballast water discharge in the Great Lakes of USA, but others have argued that many approaches cannot estimate how much ballast water were discharged without report (Rup, et al, 2010, pp.256-268). In last century, two famous discharge models were developed namely Australian Brisbane (Kerr,1994) and Victoria (ENRC, 1997) respectively, further, a European model based on the calculation of the quantity of ballast water discharged in a fixed port by ship types was developed, and this model had found the relationship between the total quantity of cargo transshipped and the quantity of ballast water (Ruiz, 2000, pp.49-50).

For establishing universal standards on ballast water management, the BWMC was adopted by IMO in February, 2004 (IMO, 2004; Gollasch et al., 2007, pp.127-134). As per Regulation A-3&A-4, some vessels do not need to manage their ballast water (David& Gollasch, 2008, pp.607-615). But Exemptions in Regulation A-4 are based on risk assessment results in a relative low area which can be satisfied by the port authority. Some authors pushed the concept of same location in their studies and stated that over areas should include many small ports nearby (Gollasch et al., 2011, pp.313-340). As the research topic is about the ballast water management in Shenzhen Port waters, the study takes Gollaschet's view to consider the West and East Port area together as over arrears.

Although in global scope, many countries restrict the ballast water through their domestic legislation or prepare to ratify the international standards --- BWMC combined with guidelines. However, comparing to those countries, China government performs very weak on establishing an entire mechanism for prevention the invasion species. So the regulatory and non-regulatory approaches on control of ballast water should be set up and such urgent situation will push the maritime administration to fulfill their responsibilities as they shall do.

Chapter2

Study Background of Ballast Water

2.1 Background of ballast water

For a steel ship, ballast water plays important role in her stability and manoeuvr ability aspects when she is not carrying cargo or not carrying heavy enough cargo. In the global scope, ballast water is taken from one place to another place thousands nautical miles far away where the water may be discharged in a completely different ecosystem as invasive creatures (Carlton, 1999). Annually over 10 billion tons of ballast water are transferred among ports (Oemcke&Leeuwen, 2003, pp.65–76), and about 3000-4000 million tons of untreated ballast water are discharged from ships every year in ports for cargo loading work or in coastal waters when vessels prepare for entering ports (Carlton &Geller, 1993, pp. 78-82). Sometimes, invasive creatures can damage local marine environment seriously (Holeck, 2004, pp.919-929).

The organism living in the coastal waters may pumped by ships with ballast water, especially when a vessel pumps water in the shallow area, the water associated sediment may be pumped into ballast tanks. Ballast water is released accompanied with the microbes, so non-native organisms will affect the local marine environment. In addition to the impact of ecology and contribution to the extinction of the local species, the more significant threat is that the invasive species may also lead to socio-economic damage. The impact of the health of the human body is reported from the invasive species by altering native food chain.

2.2 Actions taken by different parties

Typically, there are two basic ways to deal with bio-invaders: stop them or remove the invading creatures. It is impossible to stop the invaders, however, preventing invasions is the more practical and economical solution in the long run.

In order to stop the invasion, the microorganisms may be killed during the voyage so that they cannot be discharged from the ballast tank. Now many researches are needed to conduct for preventing the introduction of harmful species by this method, unfortunately, there is no ballast water treatment method that can completely get rid of the invasion risk by exotic species. The goal of managing ballast water is to minimize the risk of potential species as reasonable as possible.

2.2.1 Global Response

In 1992, the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro aware the recognition of invasion species as a major international concern. In 1997 the MEPC as a branch of IMO adopted Guidelines in the form of "*Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens*".

Members of the international maritime organization are required to adopt compliance these guidelines for reducing the risk of the transfer hazardous substances. After years of negotiation, the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* adopted in February , 2004 finally. These guidelines strongly recommend the owner and operators to install compliant ballast water treatment system on their ship.

Although the Committee strongly recommends approval of the BWM convention, participation of EU in ballast water management is limited. A useful resource for alien species invasion can be assessed in the Web Site: www.europe-aliens.org, but it only provides a few cases with possible costs of damage caused by invasion species (Europe-aliens, 2015).

As early as in the 1980s, Canada and USA had recognized the damage brought by the ballast water from ships and they provided the earliest suggestions to the international society for controlling the ballast water. United States required that all ships in the great lakes or the Hudson River on the George Washington Bridge Road to the high seas shall exchange ballast water before a ship enters the channel (Carlton,2000,pp.19-33).

Although China is not a State Party for BWMC, more and more people recognize this serious problem in the society (Du, 2009, p.98). There is no mandatory approaches on how much maximum reduction should be taken for reduce the risk of the ANS introduction from other regional waters according to the prevailing law. Due to the transfer of nonindigenous species via ballast water is an international issue, regulations for the management of ballast water should be solved in the UN convention frame work, as the UNCLOS requirement, States should work together to prevent the introduction of harmful or invasion species (UNCLOS, 1982).

2.2.2 BWM Convention status

The Convention will take effect from 12 months after the date of the 30 countries (which the combined merchant fleet is not less than 35percentage of gross tonnage of world merchant ships) has been approved. So far, 26 states has ratified it, covering 24% of the of the world merchant fleet.

In this convention, D-1 requests the exchange ballast water in the middle ocean, while D-2 regulation requires ballast water treatment; both of the two requirements have their own timescales (See Table 1).

Table - 1: Timescales for ballast water exchange and treatment.

Build date	Ballast water capacity (m3)	2009	2010	2011	2012	2013	2014	2015	2016
Pre 2009*	1,500 – 5,000			D1 or D2				D2	
	< 1,500 or > 5,000				D1 or D2				D2
2009 onwards	< 5,000				D2				
2009 to 2011	> 5,000				D1 or D2				D2
2012 onwards	> 5,000						D2		

Source: Lloyd's Register(2010). Ballast water treatment systems. London: Author.

Specially ,for ships built in 2009, the Resolution A.1005 allows the delay of compliance until second years of annual survey but not later than December 31, 2011. According to MEPC140 (54), ships participate in the Maritime Organization "prototype program" will be allowed to meet the requirements of the D-2 within five years before the date listed in Table 1. MEPC has conducted several reviews to determine whether the appropriate technology can meet the standards of D-2 agreement.

The BWM convention D-3 requires that the ballast water management system for compliance of the convention must be approved by the competent authorities under the requirement of ballast water management system (G8) by the competent authority. The D-3 also requires ballast water management system using active substances (G9) compliance with this Convention shall in accordance with the procedures of the International Maritime Organization. Program (G9) is made of two layers process - basic and final approved - to ensure ballast water management system that does not constitute unreasonable hazardous environment and human health.

2.3 The mainly disposal methods

In fact, there is no ballast water management method can eliminate the invasion species completely and these methods are not both universally applicable and effective prevention ANS. But for MOE, it has been used and is still using (James et al, 1992, pp.145-159). In fact, MOE presents same safety risks and other limitations but no single technology can solve this problem. As a most possible or feasible method but a comprehensive approach, MOE can be used widely before some alternative eventually enhance ballast power management level.

Basically, the mainly treatment methods at the current technology level concerns on killing the invasions species by physical, chemical and biological approaches(Tamburri, 2002,pp.331-341; Smayda, 2007, pp.601-622).

2.3.1 Brief introduction of MOE method

MOE method, short for mid-ocean exchange is the most current method to control the invasion creatures in the ballast water. Usually, such exchange action was taken at a distance from the shore more than 200 nautical miles, in the area where it’s deep more than 500 meters. Other methods such as ballast water treatment or disposal of the wharf are only used in special cases which are currently in research or demonstration phases.

However, as a control strategy of ballast water, MOE method is a modest effectively way for prevention nonindigenous species invasion (Dragsund et al, 2005, p.131). The success of this management method is determined on the entrained organisms in the exchange process of ballast water. Indeed, this approach is not entirely successful, 95% of the water exchange resulted in flush only 25% to 90% of the organisms in Great Lakes where ocean ballast water exchange is mandatory during that time (David, 1998, pp.607-615). The Mid-Ocean exchange method is depended on the efficiency of flushing of organisms, and the impact of salinity pressure changes in ballast tank should reduce significantly. The disadvantages of the exchange ballast water management in the ocean include the structurally designed of merchant ships that does not safely allow ballast water exchange in the ocean. Particularly in rough weather condition, it is impossible for ship to achieve the exchange successfully. Regarding to the invasion species, many of them can survive in a very wide range of salinity environment.

2.3.2 Physical separation

The physical separation contain several different processes, it is basically capped at the screen and disk filter and / or hydro-cyclone separator. Several systems use 3 or more processes. The popular designs are: Filter+UV+O_3/orFilter+US+O_3/or Filter+electrolysis+US/or Shear+cavitation+O_3 (Tang et al., 2006, pp.410-423).

In general, hydraulic cyclones are not proven to be very effective, but they are still active in exploiting in a few BWT systems program (Tang et al., 2009, pp.1396-1399). Separation is used as a process by removal of larger organisms. Usually, the whole diameter is 25 - 100 microns. Sometimes the disposal efficiency can reach to hundreds to a few thousand cubic meters per hour, which also helps to reduce the amount of solid in the ballast water. Reduce the pumping rate can significantly slow down the cargo operations, so it brings consequent economic impact to operators.

2.3.3 Biological treatment

In the BWT system, using biocide including chemicals as a treatment method has developed rapidly in recent years. The oxidant solution, chlorine dioxide, per-acetic acid non-oxidizing chemicals are used widely. The use of chemical fungicides needs to be designed adequately for avoiding unnecessary emissions of the fungicide residues. Another problem with the use of chemical killed biological agents is that it has the potential for production of by-products such as three halogen methane and halogen acid (Wang et al, 2005, pp.153-161).

2.3.4 Physical-Chemical processes

Physical - chemical method is by way of ultraviolet (UV) and ultrasound (US) radiation, shear / cavitation DNA.

Although most of the existing systems are based on the conventional water treatment process, the technology of the DNA has been specially used for ballast water treatment and development.

Chapter 3

Ballast Water Management Status in Shenzhen Port Waters

3.1 Port of Shenzhen profile

Shenzhen port is located in the south of China (See Figure-1), adjacent to the North East -Asia international shipping routes, which are divided by west and east areas (See Figure-2 and Figure -3). From the support of the Pearl River Estuary and Shenzhen, Hong Kong port enjoys efficient transport. As an important regional hub and container port in China, Shenzhen plays important role in the development of Pearl River Estuary. Annually, nearly 200 million tons of cargo and over 21 million TEUs, 4 million passengers, shipped or transferred by Shenzhen port. Overall, Port of Shenzhen is a multi-purpose port, where many different types of vessels discharge or load cargo there. As the main center in Shenzhen, the West port area is always bearing heavy ship traffic. It is estimated that more than two hundred 300 +DWT vessels load or discharge there per day. (Shenzhen MSA, 2015).

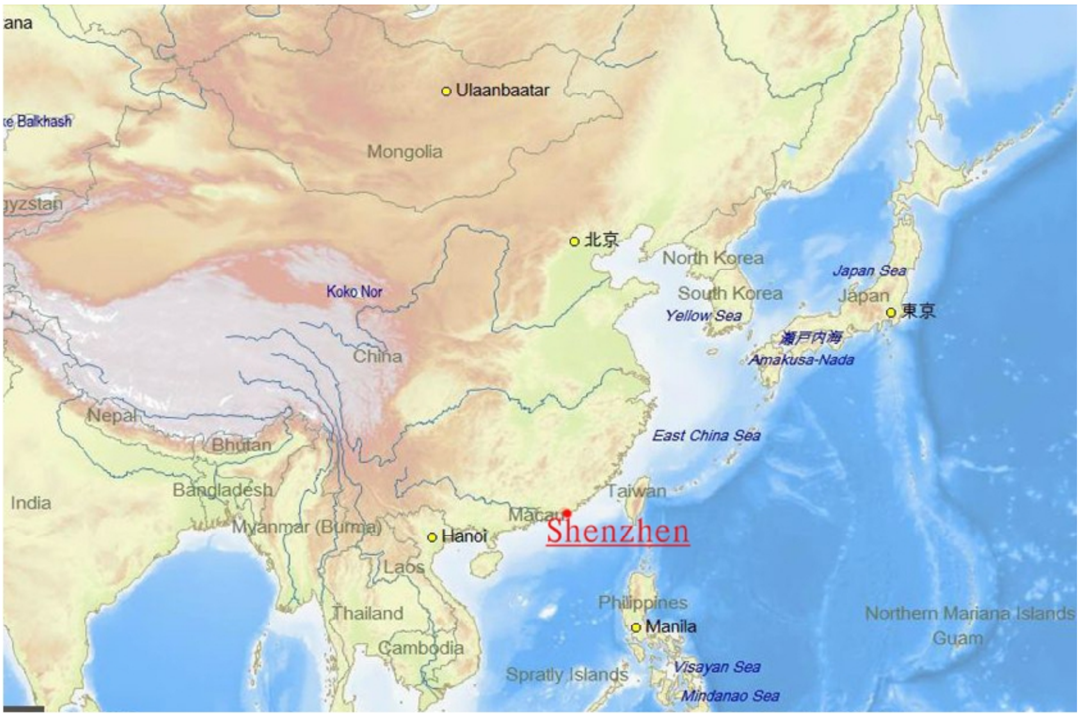

Figure-1: Geography location of Shenzhen Port

Source: The Author.

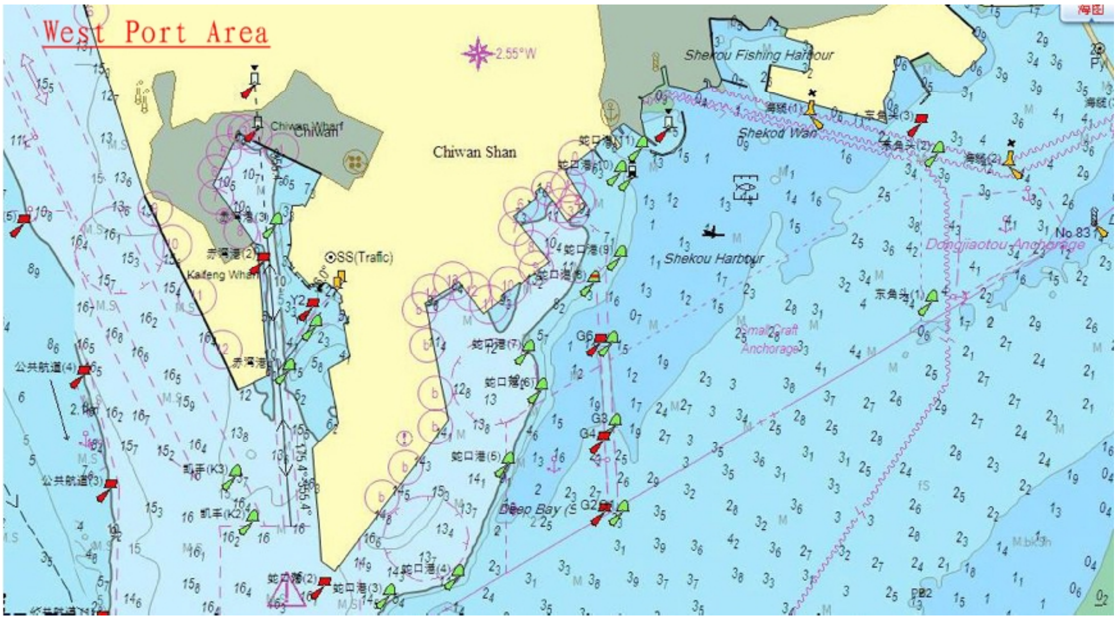

Figure-2: The West Port area of Shenzhen Port

Source: Author.

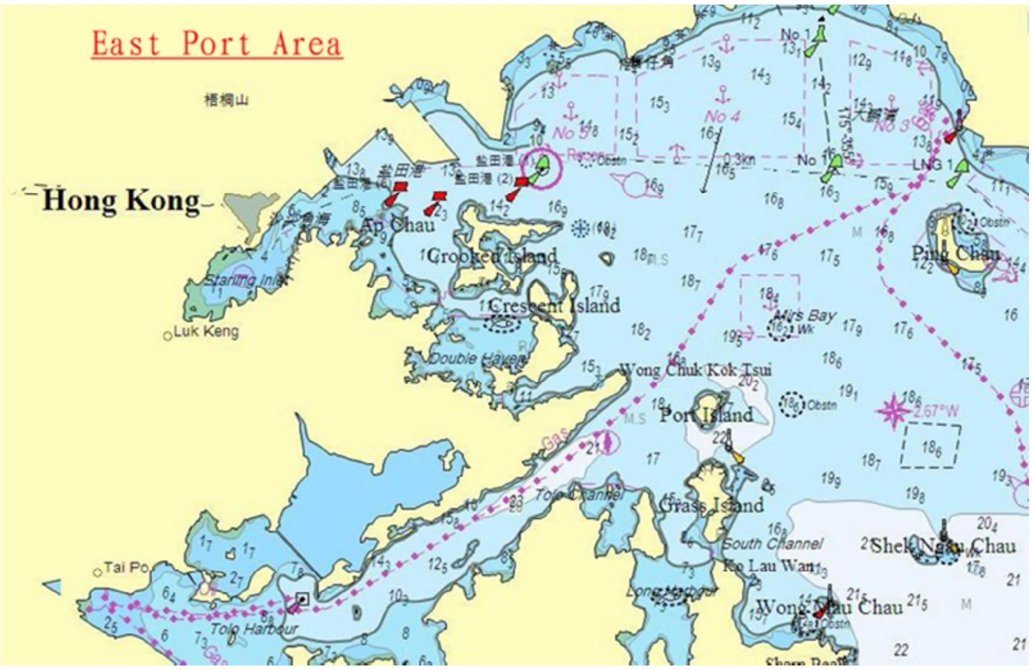

Figure -3: The East port area of Shenzhen Port

Source: The Author.

3.2 Cost analysis of control ballast water in Shenzhen port

3.2.1 Potential costs of controlling ballast water

For a single vessel, it is estimated that the cost of employing ballast water treatment methods vary depending on the equipment. General speaking, it range from thousands to hundreds of thousands of dollars. In Shenzhen port waters, the initial cost of international convention may exceed one billion US dollars at the assumption that one thousand vessels berthed in Shenzhen port have installed such treatment equipment.

3.2.2 Potential costs of not controlling ballast water

Invasive species cause massive economic losses on local marine environment. According to the US report, it is estimated that economic loss was more than $50 billion a year in USA, mainly effect on agriculture (Carlton&Holohan,2000). This situation is very similarly compared to China, for Shenzhen region, it may bring even worse to the Pearl River. Invasive Species threaten the native species, and now some native species in Pearl River waters are extinction. The annual loss could be calculated by billions (Wang et al, 2015, pp. 633-724). Beside, ecological damage caused by invasive alien species can be enormous. More than half of the invasive species are disturbing the food chain in local marine environment.

3.3 Biological Experiment and Inclination Treatment Status

3.3.1 Biological experiment

By using real survey conducted on vessels and ballast water in the Port of Shenzhen, data for analyzing the damage of local marine by invasion species are collected. The results show that the discharge of ballast water with has high relation to the local microorganism in the marine environment. Understanding the aquatic organisms transfer process by way of biological invasion from ballast tanks is a key to effective management of ballast water (David, 2007).

3.3.2 Vessels to be selected

Vessels along to the Shenzhen berth engaging on international shipping are selected for the experiment. Many of them experienced trans ocean voyage for more than five days, whose ballast water is sent to the lab for analyzing the discrepancy compare to local sea water (See table -2).

Table -2: Samples to be selected for analyzing the ballast water

Sequence of sample	**The country contained in the group of sample ports**	**Ballast water resource**
WP1 ,WP2,---,WP100	South Korea, Japan, South east Asia countries, Singapore	West pacific and the coastal countries waters
EP1,EP2,---,EP100	West coast port of Canada and USA, like Long beach	East pacific and the coastal countries waters
EU1, EU2, ---, EU100	UK, Netherlands, Germany etc.	North sea or European port waters
GU1, GU2, ----,GU100	Persian Gulf coastal countries	Persian Gulf
AT1,AT2,---,AT100	East of north America	North Atlantic coastal waters
BR1,BR2,---,BR100	Brazil	South Atlantic coastal waters
IN1,IN2,---,IN100	India, Sri Lanka	India ocean coastal waters
PE1,PE2,---,PE100	Perth, Australia	Australia
AU1,AU2,---,AU100	Brisbane ’Australia	Australia

Source: The Author.

3.3.3 Sample collection

Before collect samples, crews in engine room are asked to open cabin ballast water circulation system to enable the ballast water cycle at least 10 minutes. After that, a total of 10L water is collected from the bottom of ballast tank by Plexiglas. For analyzing the initial bacterial properties of the ballast tanks, the sample will be sent to the *Shenzhen Entry-Exit Inspection and Quarantine Bureau* lab immediately.

3.3.4 Biological experiment evaluation

Each dilution offers independent AGR of bacteria in different densities. The sample was put on a selective plates at 37 ℃ environment stay for 24h or 48h, then purified the different bacteria by size, color or shape. All pure cultures are identified by API20E or 20NE (bioMérieux, France), if necessary, the biochemical test project will also be conducted as supplement. Classical multi-dimensional scaling is mainly approach adopted in the experiment which can obtain similarity expression space between samples. With the help of the software Matlab7.0, if a kind of bacterial species could be detected, this sample will be remarked as “1”, and otherwise, it will be detected as “0”(Trosset& Priebe, 2006,pp. 4635–4642). Hence, those numbers can compose "boat (m) × bacteria (n)" in the matrix. The formula can be expressed as following equation:

$$d^2rs=︵X_r-X_s︶︵X_r-X_s︶' \quad (1)$$

where $1 \leqslant r \leqslant m$ 、$1 \leqslant s \leqslant m$. m × m-dimensional distance matrix D is converted by the formula, by which the length (m-1) *m / 2 is regarded as output vector. All those calculation results are normalized by the function "z score" by the software Matlab 7.0. Finally, using function “cmd scale” converted “D” into m × p-dimensional ($p \leqslant n$) structure matrix Y (Jennings& Mckeown,1992,392-396).

With the help of IBM SPSS STATISTICS software, the 188 samples are analyzed automatically (See Figure-4). The samples PE 14, BR10 and AU11 are most far away from the center, which means that the ballast water source from Australia and Brazil are very different from others. This part of ballast water is mainly a key concern for port authority.

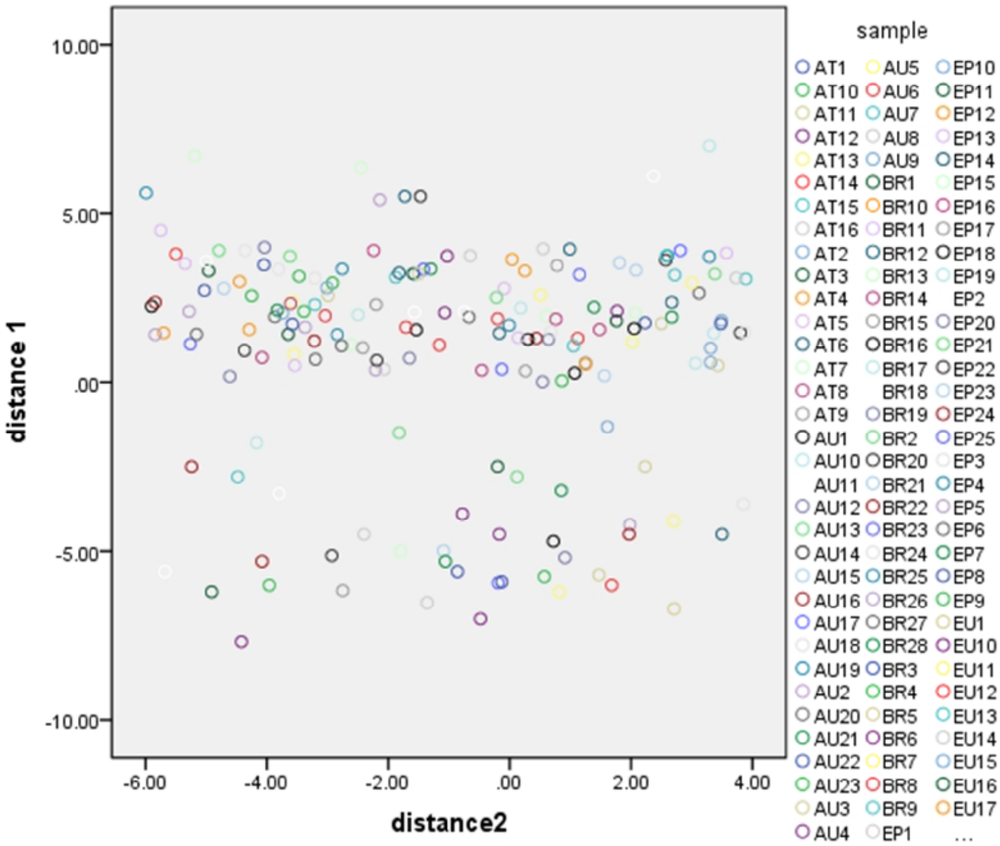

Figure-4: Classical multi-dimensional scaling of 188 samples collected

Source: The Author.(Note: the distance values were get from the lab by professional staff)

Regarding to the categories of bacteria, there are more than forty kinds of bacteria detected in the ballast water sample (See Table-3).

Table –3: Mainly bacteria detected in the ballast water sample

Sequence	Bacteria Name	Abbreviation (code)
1	Aeromonashydrophila	AERO1
2	Vibrioalginolyticus	VIBR1
3	Vibriovulnificus	VIBR2
4	Vibrioparahaemolyticus	VIBR3

5	Escherichiacoli	ESCH1
6	Burkholderiacepacia	BURK1
7	Enterobacter cloacae	ENTE1
8	Enterobacteraerogenes	ENTE2
9	Citrobacterbraakii	CITR1
10	Citrobacterfreundii	CITR2
11	Klebsiel- laornithinolytica	KLEB1
12	Vibriometschnikovii	VIBR4
13	Vibriocholerae	VIBR5
14	Aeromonassalmonicidas	AERO2
15	Aeromonassobria	AERO3
16	Proteusmirabilis	PROT1
17	Klebsiellapneumoniae	KLEB2
18	Kluyveraspp	KLUY1

3.4 A voluntary program in Shenzhen port

Because Shenzhen port maritime authority has no mandatory requirement for exchange ballast water, for better analyzing in what extent MOE approach effects on the ballast water, the author visited international vessels for encouraging four captains to join a voluntary program successfully about the ballast water should exchange and when the ship in the midway of her voyage in April 2015. The program require that each vessel only exchange one DBT ballast water if necessary, other water in tanks will be done as comparison. Four groups of ballast water are collected and each dilution provides an independent estimate of the apparent growth rate (AGR) of bacteria at different grazer densities. The lab analyzes the AGR by the calculation formula as follows:

$$AGR\ (d^{-1}) = ln(p_t/p_0)/t \qquad (2)$$

Where t is the duration of the incubation and P_o and P_t are the initial and final bacterial abundances (Elser, et al,1995, pp.105-110). Four groups of dilution experiments were conducted to assess the exchange effect of micro zooplankton. Due to time and space constraints, the culture time was not more than 48 hours.

Table-4 Bacterial abundances when four vessels arrived at Shenzhen port

Sample Number	Ship's type	Exchange position	Duration (days)	bacterial abundances when arrive at Shenzhen port(cells/L)	
				exchanged Water(MOE tank)	unchanged Water
1	Bulk carrier	26°06'16"N 135°22'60"E	6	About $8* 10^8$	About $3* 10^9$
2	containership	8°20'25"N 94°32'48"E	6	About $2 * 10^9$	About $3* 10^9$
3	containership	35°10'50.5"N 150°25'37.7"W	7	About $3 * 10^9$	About $5* 10^9$
4	Oil vessel	6°09'38.0"N 92°19'10.8"E	6	About $2* 10^9$	About$6* 10^9$

Source: The Author (The data of bacterial abundances are provided by Drinking Water Supply Company in Shenzhen)

The physic characteristics of the four group samples are very different, for example, the COD of the ballast source from the Pacific Ocean can reach to 1.4 mg/L, and by contrast, the lowest value is only 0.6 mg/L which is from the India Ocean.

The top 5 bacterial abundances in this volunteer program founded was VIBR1,VIBR2, ESCH1, PROT1, and AERO1. After 48 hours culture in the lab, the comparison of four groups sample in this program show that exchanging water in the ocean can significantly restrict the growth of micro zooplankton (See Figure -5). Particular as the time goes on, bacterial abundance decrease due to the space and nutrition restrict the growth of such microorganism.

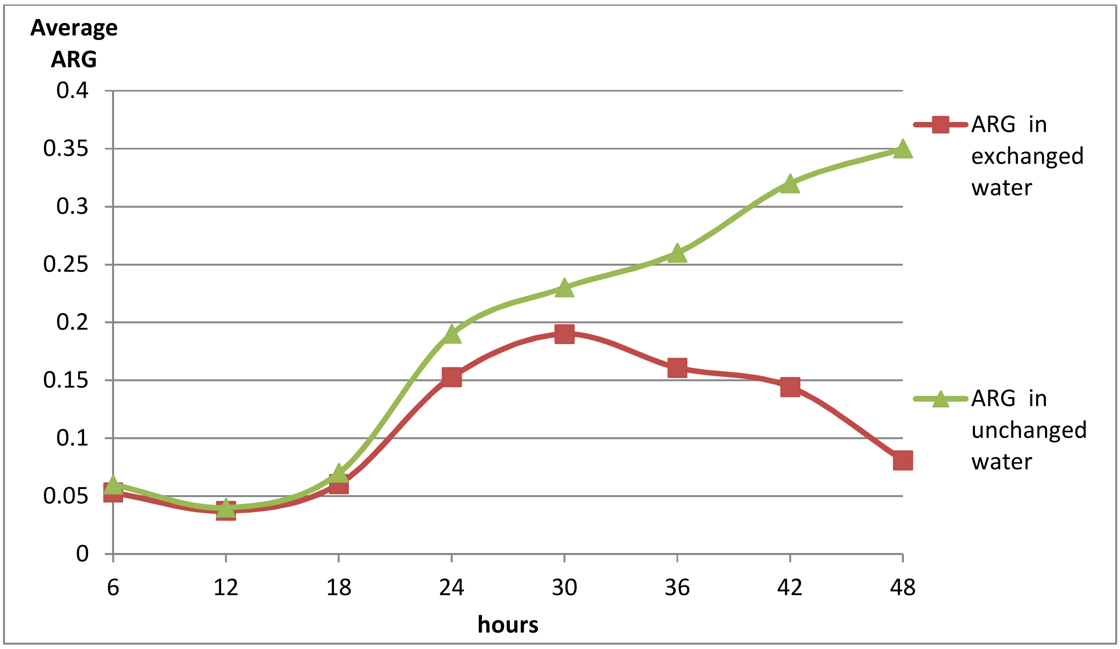

Figure -5: Average ARG trend in 48 hours
Source: The Author.

3.5 Questionnaire and inclination analysis

Shenzhen port ranks in the top 5 in china, with many shipping business and international shipping company branches. A questionnaire was developed for vessels alongside the Shenzhen port and company policy for ballast water management in response to the BWMC, which were surveyed in the same time (See Table 5).

Table 5: Questionnaires for vessel in the Shenzhen port berth

Q1: How often did your vessel treat the ballast water in the past voyage?
A1: A: ALWAYS B: OFFEN C: SOMETIMES D: NEVER
Q2: By what means your vessel treated the ballast water?
A2: A:MOE; B: NEAR SHORE EXCHANGE; C: PORT; D:SHIP BOARD TREAT EQUIPMENT; E: NO DISCHARGE

According to the questionnaire, a figure is given to show that the ballast water treatment statuses when the vessels enter Shenzhen Port. The treat method listed in the table include MOE approach (only consider 500 nautical miles away from Shenzhen port where a ship is in a deep South China sea or West Pacific), near-shore exchange (within 500 nautical miles from the nearest land of Shenzhen port), in-port exchange, ballast water management system and no discharge. Most vessels choose MOE option, followed by in-port exchange method (See Figure-6).

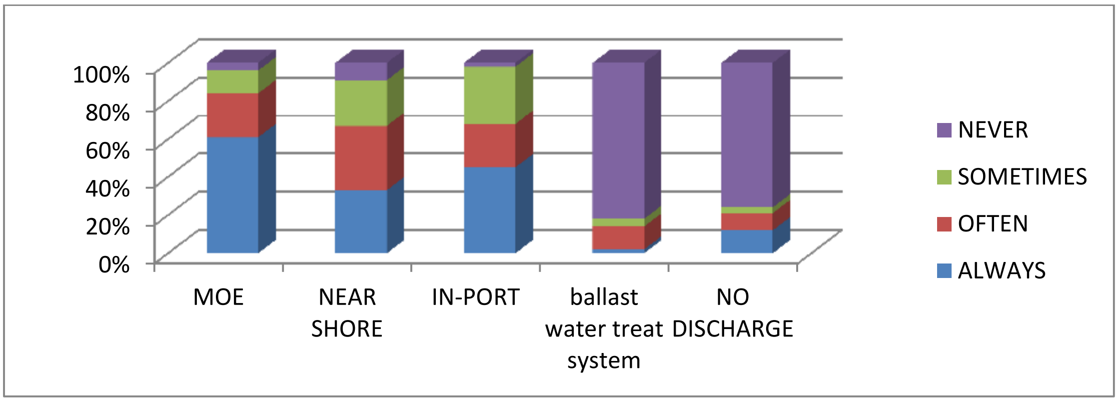

Figure -6: Survey on ballast water treatment in Shenzhen Port

Source: The Author.

3.6 Brief summary of this Chapter

The physical-chemistry characteristic in Shenzhen Port is very different from other place in the word by help of dilution effect contributed by Pearl River, so MOE approach can be used for preventing the invasion species. Because China government has not ratified the BWMC by far, considering that many vessels can hardly meet the requirement of D-2 standard of this convention. Understanding the comparison result is very obvious for decrease the ARG, adopting the international approach --- MOE can be a good solution for addressing this issue in the prevailing condition which will be considered to be an important proposal in the following Chapter.

CHAPTER 4

Risk Assessment Algorithm for Targeting Ship in Shenzhen Port

The above Chapters have identified the high risk of transmitting the ANS from vessels in Shenzhen Port, but how to assess and category the risks are still in question. This Chapter is to clarify a risk assessment algorithm which first applied on Baltic Sea (Gollasch & Leppakoski, 2007, pp. 313-340). The Baltic Sea model has been applied, and the assumptions did not effect on the assessment, so the quality factors affecting the ballast waters physical characteristic can be referred well. Several conditions are given to different weight of the total value including the salinity gradient, temperature, the route and resource of ballast water which has been evaluated in the lab listed in Chapter 4. The purpose of risk assessment algorithm is to identify the risk category carried by different vessels in Shenzhen Port. This analysis is based on entire information report database including many important parameters. So establishing a mandatory report system is significant for this assessment approach which also will be regarded as a proposal in the following Chapter. According to the IMO A.868 (20) resolution, it is strongly recommended the Shenzhen authority set up a computer system to record the position and time of ballast water as a kind of electric log book for vessel enters Shenzhen Port, and to make the data assess available.

As a valuable aid for decision making, the risk assessment approach can be referred to the G7 standard by qualitative or quantitative style.

4.1 Risk of water origin

4.1.1 Salinity gradient analysis

Salinity gradient is a key element for the living of ANS, the risk of which can be measured as level of origin water where ships pump by category from high, medium to low (Santagataet & Gasiūnaite, 2008, pp.61-76). Risk grade can be expressed in the number from 1 to 9 by the different salinity gradient levels (See Table 6).

Table–6:Shenzhen Port waters salinity risk grade

Salinity risk grade		
Salinity grade ratio= salinity level in ballast water [‰]/ salinity level in Shenzhen port waters [‰]	Risk range	Weight number
3< Salinity grade ratio ≤1	Low	1
1< Salinity grade ratio ≤2		2
2< Salinity grade ratio ≤3		3
3< Salinity grade ratio ≤4	Medium	4
4< Salinity grade ratio ≤5		5
5< Salinity grade ratio ≤6		6
6< Salinity grade ratio ≤7	High	7
7< Salinity grade ratio ≤8		8
Salinity grade ratio >8		9

Source: Author.

4.1.2 Temperature

Similarly, the temperature risk also can be categorized by three levels namely high, medium and low ranks depending upon the temperature ratio compare to the donor port. Specially, the difference between salinity grades is that the weight number has indirect linear relationship with the grade ratio (See Table 7).

Table -7: Shenzhen Port waters temperature risk grade

Temperature risk grade		
Temperature grade ratio= temperature level in ballast water [‰]/temperature level in Shenzhen port waters [‰]	temperature range	Weight number
3<Temperature grade ratio ≤1	High	9
1<Temperature grade ratio ≤2		8
2<Temperature grade ratio ≤3		7
3< Temperature grade ratio ≤4	Medium	6
4<Temperature grade ratio ≤5		5
5<Temperature grade ratio ≤6		4
6<Temperature grade ratio ≤7	Low	3
7<Temperature grade ratio ≤8		2
Temperature grade ratio >8		1

Source: Author.

4.1.3 Time effect

In a short voyage scenario, the ballast water must source from a neighboring port where it has the similar marine species so that the survival rate of the ballast organisms will be higher, thus making the risk rank of such ship increases. By contrary, a longer voyage may lead microorganisms die or those species cannot be used to different marine environment, so the more time stays in the ballast tank the less living ANS can survive in the local marine environment (Behrens et al, 2005).Hence, the voyage time is another key element for assessing the risk ranks (See Table - 8).

Table-8: Voyage time risk grade

Voyage time grade		
Voyage time (days)	Voyage time range	Weight number
0<Voyage time≤1	High	9
1<Voyage time≤2		8
4<Voyage time≤3		7
4<Voyage time≤5	Medium	6
4<Voyage time≤5		5
5<Voyage time≤6		4
6<Voyage time≤7	Low	3
7<Voyage time≤8		2
Voyage time>8		1

Source: Author.

4.1.4 Water source evaluation

According the experimental test in the Chapter 4, the route selection has a strong relationship with the living ANS expressing by AGR due to the source of the ballast water has various physical-chemistry characteristics. By using the Classical multi-dimensional scaling approach and the samples analysis listed in the Chapter 4, and assuming other regional waters is in the medium level, the water source risk level can be specified (See Table -9).

Table -9: Water source risk grade

Ballast water resource	**The country contained in the group of sample ports**	**Weight number**

West pacific and the coastal countries waters	South Korea, Japan, South east Asia countries, Singapore	6
East pacific and the coastal countries waters	West coast port of Canada and USA, like Long beach	8
North sea or European port waters	UK, Netherlands, Germany etc.	8
Persian Gulf	Persian Gulf coastal countries	7
North Atlantic coastal waters	East of north America	9
South Atlantic coastal waters	Brazil	9
India ocean coastal waters	India, Sri Lanka	5
Australia1	Perth, Australia	9
Australia	Brisbane ’Australia	4
Shenzhen port waters	Shenzhen, Hong Kong, Dongguan	1
North Domestic waters	North of Xiamen port	7
South domestic water	South of Zhanjiang	4
Other waters		5

Source: Author.

4.1.5 **The total water risk calculation**

The total risk is calculated by the sum of all the salinity risk, temperature risk, time risk and water source risk together with expressed in three different risk levels (See Table -10).

Table -10: Total water risk ranks

Risk level	Total weight number scope
HIGH	28-36
MEDIUM	13-27
LOW	4-12

Source: Author.

4.1.6 Example of origin water risk assessment in Shenzhen Port

By using the algorithm demonstrated in the above analysis and the samples listed in the Chapter 4, all samples can be calculated in the Shenzhen Port by the frequency of weight number (See Table -11).

Table -11: Frequency of weight number

Frequency of weight number					
Risk ranks	Weight number	frequency	percentage	Valid percentage	Accumulated percentage
Low area	6	4	2.1	2.1	2.1
	7	7	3.7	3.7	5.9
	8	5	2.7	2.7	8.6
	9	7	3.7	3.7	12.3
	10	4	2.1	2.1	14.4
	11	5	2.7	2.7	17.1
	12	3	1.6	1.6	18.7
	13	8	4.3	4.3	23.0
	14	8	4.3	4.3	27.3
	15	9	4.8	4.8	32.1
	16	12	6.4	6.4	38.5
Medium area	17	6	3.2	3.2	41.7
	18	7	3.7	3.7	45.5

	19	10	5.3	5.3	50.8
	20	10	5.3	5.3	56.1
	21	5	2.7	2.7	58.8
	22	12	6.4	6.4	65.2
	23	6	3.2	3.2	68.4
	24	5	2.7	2.7	71.1
	25	2	1.1	1.1	72.2
High area	26	8	4.3	4.3	76.5
	27	7	3.7	3.7	80.2
	28	7	3.7	3.7	84.0
	29	5	2.7	2.7	86.6
	30	6	3.2	3.2	89.8
	31	10	5.3	5.3	95.2
	32	4	2.1	2.1	97.3
	33	2	1.1	1.1	98.4
	34	3	1.6	1.6	100.0
	total	187	100.0	100.0	

Source: Author.

Vessels in high risk will be the targeting vessel for conducting the PSC inspection, and the data will be input into a computer programme to be queried at any time. For local authority, about 32.6% of vessels are in the high risk region. According the annual report 2014 provided by the Shenzhen MSA, number of ships arriving and departing Shenzhen Port had reached to 370,100 in total (See figure -3). In practice, if only control 32.6% of the vessels, the work should be very hard to accomplish. Hence, regional legislation on the ballast water control may be a better solution.

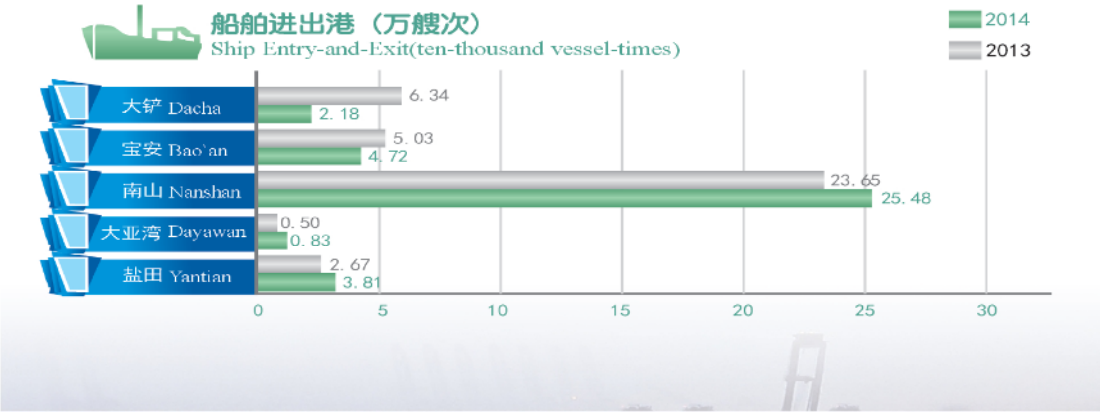

Figure -7: The statistic of Ship entry-and- exit in Shenzhen Port

Source: Shenzhen MSA (2015). Shenzhen, China. Shenzhen: Author.

4.2 Risk of vessels

Risk assessment of vessel is very similar to the Tokyo MOU which includes the ship performance and company performance. It is easy to find a ship performance from the Tokyo MOU computer system (http://www.tokyo-mou.org), so the weight number of ship can be got.

4.3 Total risk matrix

The total risk of ballast water has a direct relation to the ship's discharge volume, obviously, the more volume of ballast water discharge, the threat to the local marine environment will be more serious (Gollasch & Leppäkoski, 2007, pp.313–340).For convenience, the value of ballast water is expressed by weight (See Table - 12).

Table -12: Risk ranks of ballast water discharged (Unit: Ton)

Risk ranks of ballast water discharged by volume		
Ballast water discharged (Unit: Ton)	Voyage time range	Weight number

value≤5,000	Low	1
5,000<value≤10,000		2
10,000<value ≤15,000		3
15,000<value ≤20,000	Medium	4
20,000<value ≤25,000		5
25,000<value ≤30,000		6
30,000<value ≤35,000	High	7
35,000<value ≤40,000		8
40,000<value		9

Source: Author.

So the total risk can be calculated by the following equation:

*Total risk = (Risk of ships + Risk of origin waters) * discharge volume* (3)

By adding the ship risk, the overall risk assessment of ballast water can be categorized by rank of high, medium and low (See Table -13).

Table -13: Ballast water risk level

Risk level	**Total weight number scope**
HIGH	31-45
MEDIUM	16-30
LOW	5-15

Source: Author.

The total matrix can be found from the matrix form (See Table - 13). As it is discussed above, the overall vessel number of entry and exit of Shenzhen Port is huge, so the key work should be put on the HH area firstly. For control and management well of ballast water from the maritime administration perspective, targeting vessel should be selected from the Tokyo MOU computer database, then PSC and FSC inspections will contribute to enhance the ship performance and company management level by strict regional legislation and environment penalty.

Table -14 Risk matrix

Risk ranks of ballast water discharged by volume	Ballast water risk level		
	H	M	L
H	HH	HM	HL
M	HM	MM	ML
L	HL	LM	LL

Source: Author.

CHAPTER 5

Proposals for Shenzhen Maritime Administration on Ballast Management

5.1 Medium term proposals

5.1.1 Experience of regional legislation

It is known that ballast water is a high-risk contribution of species invasion to local marine environment that shall not be discharged at will. The US has passed legislation on MOE approach for ballast water management (Code for Federal Regulation. 33 CFR 151 D, 2012). Before, Australia has also developed such regulations (The Australian Quarantine and Inspection Service, 2011). EMSA proposed a workshop titled *Ballast Water Management Convention (BWM) Implementation* -to help the Member States fulfill the international convention in EU level 1n 2008 (Meer, 2012).

5.1.2 Steps

Step 1: Procedures

Risk assessment of ballast water management should be established on a whole system which all procedures being employed to inform coastal risks brought by illegal discharges. So far, all reporting information and measures is used almost through voluntary participation. Shenzhen maritime authority should set up a local standard including exemptions and additional measures as described in the BWMC.

Step 2: Data collection and further guidance

There were 550,000 port calls in 2014 (Shenzhen MSA, 2015). The data collection work would be very complicate if all ballast water information is obtained adequately, so the best solution is to develop a data collection strategy. The first step should be focused on how to set up a science sampling strategy before China government ratifies the BWMC. This technology issue should be determined after discuss with sampling experts in order to fund a feasibility evaluation approach. The regional sampling program or procedure should be objective to review better regulations\protocols or procedures\options for ballast water sampling and can also identify the problems with respect to sampling. Additionally, a further research is needed for reevaluation such program.

Step 3: Identification measures

The different management measures should be reviewed and assessed for identifying the common problems. For prevention of the invasion from the international vessels, it is better to overcome any practical implementation of G9 requirements. In addition to the international prevention, the potential effect of domestic vessel discharge should be approved in a specific area.

Step 4: Technical issue and cooperation

For feasibility of estimation the potential costs and sources of local ballast water management, a cooperation programme should be developed in the national level to identify how better solution can be achieved. Although from China national scope, computer information portal has not been developed, Shenzhen MSA may take measure to use such important method for sharing best practice in the regional jurisdiction waters.

Shenzhen MSA can also try to set up such a system to contain documents on strategy and guidance on ballast management.

These Steps as key areas in which Shenzhen MSA can add significant value to preparations before China government ratify the BWMC. Also, those steps can be changed by regional legislation in future or continued to be discussed with technical experts. Typically, Shenzhen MSA should attempt to find additional measures to meet the international convention before the legislation system works properly.

5.2 proposals for prepare to comply with the Convention

5.2.1 Type Approval certification

The BWMC require maritime administration certificate to the approved systems when the system is planned to install on a ship for compliance with the convention. As a Flag Administration, Shenzhen MSA should fulfill their responsibilities to make sure their branches or RO certificate work as the requirement of IMO resolution MEPC.178 (58).

5.2.2 Basic requirement as per BWMC

According to the MEPC.127 (53) resolution, every ship should hold a *Ballast Water Management Plan* that include piping, electrical and control systems approved by the administration or a RO. Additionally, a *Ballast Water Record Book* containing the information in a proper format approved by the administration. For existing vessels, in order to maintain her in class, plans and information about the ballast water treatment system and its installation should be submitted to the ship's classification society for initial or annual survey. It is predicted that in a short future the convention will be put into force, every ship over 400 GT will be required an initial survey that include but not restrict to an approved BWMP, BWMB and equipment arrangements on board. However, the biological efficacy is not regulated in this convention (Wright, 2012, pp. 17-23). The annual intermediate and renewal surveys aim to confirm that ballast water management arrangement is no changes compare to last survey and an approved BWMP is on board. Accordingly, the treatment system is in good order. It also has been operated and maintained well.

5.3 Recommended regional strategies

China government has not ratified the BWMC so far. But it does not influence Shenzhen MSA on promulgating the regional control strategies for exercise effective measures on controlling ANS invasion. Additionally, the Convention allows the port state to implement their responsibilities on foreign vessels. There is no most-favoured-nation treaty for sanction ships that violate the regulations.

5.3.1MOE method

It is recommended that the experts reevaluate the MOE method for ballast water management systemically as the experiment show that the MOE really effective apparently.

5.3.2 Designating zones for ballast water exchange

According to the BWMC, ballast water treatment equipment installed should meet the requirement of the D-2 standard after the year 2015. However, because China is not a contracting state of BWMC, 76% of vessels (Chapter3) discharge the ballast water at will without any treatment. As a result, Shenzhen port waters will be polluted seriously without restriction of discharge. Hence, adopting measure MOE and designating the discharge zones by regional legislation become a practice option for temporary (See Figure -5).

Figure- 8: An example for authority designating ballast water exchange boundary

Source: Author.

As shown in Figure -8, an example designated line painted in blue is located about 70 nautical miles of Shenzhen port Waters, and the deep of water alongside the line is approximate 100 meters. If vessels exchange ballast water out of this line before they entry Shenzhen port waters, the physical, chemical and biological characteristics of new ballast water recharged will be very similar compared to Shenzhen Port waters. Certainly, how to draw such a boundary will is in study because not only marine environment but also the safety of navigation and practice feasibility should be in consideration.

5.3.3 Enhance the role of vessel traffic reporting system

Usually, only very few information like ship's position and name is mandatory report for traffic reporting system. The existing ship declaration report regulates vessels entering Shenzhen shall fill the Pre-Arrival or Pre-Departure Report before arriving or leaving the berth. The report contains the ship's parameters, and ETA (estimated arrival time), etc. For better addressing this problem, the information like the source of ballast water should be reported by the charter agencies. Even according to the requirement of

BWMC, ships shall fill the ballast water record book properly for the further inspection. So submission of the ballast water operation record is becoming a key clue for the further analyzing and tracking. The country with stringent ballast water management like US has mandatory regulation on ballast water declaration. As an independent form, it is different from the other reporting system BECAUSE it has fixed format. If a ship cannot compliance with the ballast water requirement, the authority can prohibit its entrance or departure. For Shenzhen port, the maritime administration can consider such declaration form for ships entrance or departure.

Through legislation, many countries have implemented compulsory regulations for recording, keeping and reporting system. As a regional administration agency, it is strongly recommended that Shenzhen MSA promulgates the regulation for illustrating the details of ballast water reporting system. All information should be input on the computer which includes the ship's parameters, volume of ballast water discharge and management approaches.

5.3.4 The role of PSC

As a last line for prevent the pollution, PSC plays an important role in the maritime administration. IMO has agreed on a proposal that a trial period for port state control sampling. Consequently, PSC officers have right initiate penalty or detain the vessel during this trial period from if the sampling evidence show that the discharged ballast water does not meet the requirements of BWMC.

The basic principle of the PSC is to find whether the sampling and analysis of the ballast water treatment compliance the current standard on the requirements of BWMC. AS a member of Tokyo MOU, Shenzhen MSA shall implement the standard procedures so that sampling and analysis result can restrict the violate activities. For addressing the complex issues and arguments, IMO have promulgated the revised guidelines on ballast water sampling for trial use namely BWM.2/Circ.42. Specially, two analyzes are used to verify whether the vessel compliance with the D-2 standards. So the routine inspection of ships should in two stages. First, in an indicative stage, the documents and certificates should be checked. Second stage is called detailed inspection which is a deep inspection on a ship to identify whether she comply with international standards and regulations. The Indicative Analysis is quick inspection including naked eyes method for estimating the microorganisms. By contrast, the Detailed Analysis is a more complex inspection by which a detailed result of direct measurement on a representative sample will be got. This method is aiming to determine whether the population organisms comply with the D-2 standard finally.

But for Shenzhen port waters, the regime of PSC should address the following question with adequate penalty:

- For D-1 standard, did the vessel have sufficient enough evidence show that the exchange of ballast water was taken, and what measures they took? Did the measurement of salinity compliance the convention?
- What should Shenzhen MSA do if a vessel was found that the initial indicative analysis did not meet the requirement of D-2 standard on the living of microorganisms?
- On what inspections should be conducted if visual analysis estimates the organisms more than 50μm? How do they avoid such violation?
- How do they find a practical sampling for very large vessels?

Obviously, the time consuming on the inspection should be considerable. The process of inspection should not interfere with the safety operation and the good order. So PSCO should perform professional level with a responsible manner onboard.

CHAPTER 6

CONCLUTIONS

6.1 Discussions

It is known that compliance of the international convention should consider the cost, enforcement and implement effectiveness for government. However, the cost of species invasion is astonishing, which will threat human health and marine environment. The finance issue on controlling the ballast water discharge includes the installment and retrofitted equipment on board. Additionally, the extra time and training should also be conducted. If an approach slows down the vessel's speed or increase excess fuel consumption, the cost of treatment may be even more expensive. However, the cost should not become an excuse for escaping the treatment of ballast water.

There are many treat approaches currently, but any treatment approach should be easily to supervise for port authority. Since many treatment approaches may pose a risk to human health by aiming to kill the organisms in ballast water, if the treatment water is discharged into marine environment instead of keeping in the tanks, risks and costs may more serious than the water without treatment. Hence, it is recommended that the treatment should minimize the risk of introducing ANS. As an important proposal MOE is effective because microorganisms from coastal waters are unlikely to survive in the ocean. However, the drawbacks are very obviously and disused in this research study. Other approaches, like chemical biocides could be used to treat ballast water but the operation should be very cautious as it may bring a new problem that the residues may be hazardous. Regarding to physical methods, like heat treatment, the drawback is that this method will consume extra fuel and the effectiveness on killing microorganisms is not very obvious. Hopefully, the development of the new technologies will address this complex issue perfectly in the future. From management perspective, it is urgent for Shenzhen Port authority promulgate the regulation on the restriction of the ANS. Legislation on ballast water management and reevaluation of invasion species status should be conducted and discussed in the regional scope instead of waiting the national actions for Shenzhen port waters.

6.2 Limitations and conclusions

The experiment and sampling in Shenzhen Port waters is only effective in a fixed circumstance, as the ballast water sampling analysis needs very big database which should be observed in a long periods. So it is recommended that the port authority to set up such system in order to provide sufficient data for propose science approaches for ballast water management based on huge data statistics. But the result shows that it is urgent to initiate the manage strategies for Shenzhen Port authority in response to the BWMC. Considering the delay of ratify of BWMC of China government, multiple proposals are given for better solution of ballast management in Shenzhen port: firstly, the MOE approach should be reevaluated; secondly, areas for designation of ballast water exchange should be better planned and assessed by experts. Additionally, the management method should also be improved in term of reporting system and PSC.

Meanwhile, the main finding of this paper is that the risk matrix can help the port authority to assess the ballast water risk by considering the risk of source water and risk of ships. The new visible method can help law enforcement officers to focus on the high risk vessels, and can also be applied in a computer system in the future.

In summary, by understanding threaten brought by the ANS and the benefits of ballast water treatment, the Shenzhen Port authority should evaluate an appropriate system that suits the prevailing technologies and national conditions. If necessary, the regional legislation may be used for mitigating the environment issues before the BWMC ratified in the national level.

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