DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

BALLAST WATER MANAGEMENT IN TANKERS

by
Ceyla İNMELER

September, 2009
İZMİR

BALLAST WATER MANAGEMENT IN TANKERS

A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
In Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy
In Coastal Engineering Program

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September, 2009
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Ph.D. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **“BALLAST WATER MANAGEMENT IN TANKERS”** completed by **CEYLA İNMELER** under supervision of **PROF. DR. AYŞEGÜL İYİLİKÇİ PALA** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy.

....
Prof. Dr. Ayşegül İYİLİKÇİ PALA

Supervisor

....
Prof. Dr. Orhan USLU

Thesis Committee Member

....
Prof. Dr. Doğan YAŞAR

Thesis Committee Member

....
Prof. Dr. Adem ÖZER

Examining Committee Member

....
Prof. Dr. Ertuğrul DOĞAN

Examining Committee Member

Prof.Dr. Cahit HELVACI
Director
Graduate School of Natural and Applied Sciences

ACKNOWLEDGMENTS

This thesis has been completed with the support, encouragement and sacrifices of a number of individuals: my academic advisors, specialists in the field of study, relatives and friend. With deep gratitude, I would especially like to express my thanks to a few of them here.

My thanks go to Prof. Dr. Aysegül İYİLİKÇİ PALA who was my adviser for the thesis and who always supported my efforts with her trust in me and her positive approach to my efforts. She is the one who helped me tremendously in developing myself in this field and taught me the subjects that I was not fully informed about. Best of all, she provided me with enthusiasm about the subject on which I was working. This encouragement and enthusiasm helped and enabled me to carry on and complete this task, despite all the difficulties. For all these reasons, I thank her from the depth of my heart.

Special thanks also go to Prof. Dr. Orhan USLU, my previous advisor for the thesis who continued helping me despite his retirement from the job and his departure from the city. Prof. USLU, who has an encompassing and broad vision of the subject, provided me the intellectual and philosophical perspective on my research topic. He made the whole research meaningful and worthwhile for me. He helped me to comprehend the importance of it fully and encouraged me to contribute in this field.

My sincerest and deepest thanks go to my mother, Azra INMELER who always stood by my side with her un-wavering support and encouragement. She shared every frustration, obstacles in the way of my excitement during the long months of laborous work of research and writing. My deep gratitude to her for her endless love, patience, support and trust in me during the long years of work.

Many thanks to Mr. Selçuk SERT, previous regional director of Izmir, Undersecretariat for Maritime Affairs for standing by me and his trust in me during the difficult times of completing this thesis. I am grateful to him for providing the means for gathering data related to my thesis.

My thanks also are due to Prof.Dr. Cahit HELVACI, the director of Graduate School of Natural and Applied Sciences and to his executive secretary Ms. Serap BİÇİCİ as well as to Mr. Aslan TÜRK who were administratively supportive during the long period of completion of my doctorate thesis.

I extend my thanks to Mr. Bilal KURBAN who shared perseverantly his profound statistical knowledge on my dissertation.

I extend my thanks to Mr. Göksel VATAN who shared his time and knowledge on environmental technologies during my efforts on completing my dissertation.

My thanks also go to Chief Officer Mr. Ömer KABAKCIOĞLU, for his profound capacity of opening new windows in our technical discussions.

I dedicate this dissertation to a very precious person, Assistant Professor Dr. Mustafa ÖZERLER who passed away recently, who kindly supported me and encouraged me to regain my self assurance all along.

Many thanks to everyone who helped and supported me along the way.

Ceyla İNMELER

BALLAST WATER MANAGEMENT IN TANKERS

ABSTRACT

Marine transport allows economical transportation of large quantities of cargo in a globalized world. The gradual growth in the number of ships, and accordingly in the marine traffic becomes inevitable, considering the growth in the volume of the world marine trade in the past years. While providing the safety of the ship, the crew and the cargo in such an intense traffic, it is very important to protect the marine environment. Ships carry ballast waters, when they are not loaded, to safely manage their voyages and to have stability/strength values, similar to that when they are loaded. Tankers in particular are the main actors in the transfer of millions of different types of living organisms, since they carry ballast waters in enormous amounts. Living organisms in the ballast water that are taken from the coastal waters where the biodiversity is at the maximum, when discharged at the destination port, become invasive in an environment where they have no predator and food stock is abundant, thus causing extensive ecological and economical problems. International Maritime Organization (IMO) stated ballast water exchange methods and the acceptable amounts of living organisms in the ballast water, after the use of onboard treatment systems, as D-1 and D-2 standards, in the "International Convention for the Control and Management of Ship's Ballast Water and Sediments", which aimed at controlling the transfer of living organisms. Nowadays, physical, chemical and mechanical on-board treatment systems are developed, which use the state-of-art technology and meet the standards, conducted by treatment companies, in cooperation with researchers and scientists. Ballast water reception facilities, are recommended by the Convention to be established on-shore, are considered to be a management alternative. Thus, the dissertation includes work on determining the capacity of a ballast water reception/treatment facility which planned to be built in a refinery port with high tanker traffic. The tonnages of the arriving ships, operation time and the amount of ballast water they bring were obtained as data. With the statistical analysis of the gathering data, the suitable distribution was determined and new datasets generated by using the parameters of the distribution. The capacity of projected facility is prepared by using mass curve (ripple diagram) method with the new datasets.

Keywords: OILPOL, MARPOL, Marine Accidents, Invasive Species, Ballast Water, International Ballast Water Management Convention, Ballast Water Treatment Alternatives, On-shore Ballast Water Reception and Treatment Facility, Ballast Water Management Alternatives.

TANKERLERDE BALAST SULARININ YÖNETİMİ

ÖZ

Deniz taşımacılığı, küreselleşen dünyada, büyük miktarlarda yüklerin ekonomik olarak taşınabilmesine olanak vermektedir. Son yıllarda dünya deniz ticareti hacmindeki büyüme göz önüne alındığında, gemi sayısının ve buna paralel olarak gemi trafiğinin her geçen gün artması kaçınılmaz hale gelmektedir. Bu derece yoğun bir trafikte geminin, personelinin ve yükün emniyetini sağlarken deniz çevresini de korumak büyük önem taşımaktadır. Bu nedenle gemiler, yüksüz seferlerini emniyetli bir şekilde gerçekleştirebilmek ve yüklü durumdakine benzer stabilite/mukavemet değerlerine sahip olabilmek için balast suyu taşımaktadırlar. Özelde tankerler ise, çok büyük miktarlarda balast suyu taşımaları nedeniyle, milyonlarca farklı türdeki canlı organizmanın transferinde baş aktör durumundadır. Biyoçeşitliliğin en zengin olduğu alanlardan -yani kıyılardan- alınan balast suyunun varış limanında boşaltılmasıyla, balast suyu içinde bulunan canlı organizmaların, avcısının bulunmadığı ve besinin bol olduğu bir ortamda istilacı duruma geçmesi, günümüzde ekolojik ve ekonomik açıdan büyük sorunlara yol açmaktadır. Uluslararası Denizcilik Örgütü (IMO), canlı organizmaların transferlerinin kontrol altına alınmasını amaçlayan "International Convention for the Control and Management of Ship's Ballast Water and Sediments" konvansiyonunda, balast suyu değişim methodları ve gemiye monte edilebilen arıtma sistemlerinin kullanımı sonucunda balast suyu içerisinde bulunması kabul edilebilir canlı organizma miktarını, D-1 ve D-2 standartları olarak belirlemiştir. Günümüzde arıtma şirketlerinin, araştırmacılar ve bilimadamlarıyla işbirliği içinde yaptıkları çalışmalar sayesinde gemiye monte edilebilen, standartları sağlayan, son teknolojinin kullanıladığı, fiziksel, kimyasal ve mekanik arıtma sistemleri geliştirilmektedir. Konvansiyon kapsamında kıyıda tesis edilmesi tavsiye edilen balast suyu alım tesisleri ise bir yönetim alternatifi olarak düşünülmektedir. Bu nedenle tezde, tanker trafiği yoğun olan bir rafineri limanında kurulması planlanan balast suyu alma/arıtma tesisinin kapasitesinin belirlenmesi üzerinde çalışılmıştır. Limana gelen gemilerin tonajları, limanda kalma süreleri ve getirdikleri balast suyu miktarları veri olarak temin edilmiştir. Elde edilen verilerin istatistiksel analizi yapılarak uyum gösterdiği dağılım belirlenmiş ve bulunan dağılımın parametreleriyle yeni verisetleri üretilmiştir. Yeni verisetleriyle ardışık tepeler yöntemi (ripple diyagram) kullanılarak geleceğe yönelik kıyıda kurulması planlanan tesisin kapasitesi belirlenmiştir.

Anahtar sözcükler: OILPOL, MARPOL, Deniz Kazaları, İstilacı Türler, Balast Suyu, Uluslararası Balast Suları Yönetimi Sözleşmesi, Balast Suyu Arıtma Alternatifleri, Balast Suyu Alma ve Arıtma Kıyı Tesisi, Balast Suları Yönetim Alternatifleri.

CONTENTS

CHAPTER ONE
INTRODUCTION

Marine transport allows economical transportation of large quantities of cargo. Therefore, it is the most preferred option. The gradual growth of the number of ships, and accordingly the marine traffic becomes inevitable, considering the growth in the volume of the world marine trade. In high-volume shipping areas areas, the probability of shipborne pollution and marine accidents increase. Ship management in the safest possible way is then of great importance, in order to minimise these probabilities. One of the most important components of ship safety is its stability. Stability is provided by way of loading weight in the vessel (ballast). The first chapter of the dissertation discusses the precautions essential to prevent ship borne pollution, the importance of ballast and the impact of ballast on ship stability.

Studies show that ballast is an inevitable component of ship safety, while being potentially hazardous for seas. Living organisms in the ballast water, discharged at the destination port, become invasive in an environment where they have no predator and food stock is abundant, thus causing extensive ecological and economic problems. The most striking incidence has been for Turkey, the case of Mnemiopsis leidyi, a type of jelly fish, originating from the Atlantic Ocean, transported to the Black Sea in the 1990s, via ballast waters carried by vessels. Existing of non-predating species depleted zooplanktons, spawns and larvae which are the food stocks of anchovy, caused harm to many people who make their living on fishing in those times, as well as having adverse impacts on the equilibrium of the ecosystems and on the fishery economics, for long years. In this respect, the second chapter of the dissertation discusses the marine species in ballast water.

The International Maritime Organisation (IMO) has established a convention to control the ballast water transfers which pose a global threat, and opened for signatures of States. International Convention for the Control and Management of Ship’s Ballast

Water and Sediments includes a series of mandatory rules, as well as references to several guidelines for countries to constitute their own management plans. Various treatment technologies are being developed within the framework of the Convention, for the elimination and/or abolish of living organisms in the ballast water. The acceptable amount of living organisms in the ballast water, after the use of exchange methods and/or treatment systems has been identified as D-1 and D-2 standards by the IMO. However, evidently, physical, chemical and mechanical treatment technologies which meet the standards are not applicable to every ship type and size. For this reason, the third chapter provides information on the ballast water convention, and focuses on ballast water management alternatives and discusses the applicability of the exchange methods and treatment technologies, advantages and disadvantages and the environmental impacts.

The fourth chapter of the dissertation discusses the on-shore systems, as a management alternative. A case study introduces a projection of a treatment facility design, by using the data obtained from a refinery port in Izmir, Aliağa and determining the estimated amount of ballast operations in that port. A solution is sought for a multiple variable equation where the ship size, operation time and the amount of transported ballast water are known. As a result, determining the capacity of an on-shore ballast water treatment facility shall be evaluated.

The fifth and the last chapter of the dissertation evaluate the findings.

1.1 The International Conventions

The significant acceleration of the world marine trade volume, starting from the 1950s has been regarded as the growth in world maritime fleet, from a positive point of view, which brought increase in the risks in the seas and vessels, marine accidents, environmental disasters and economical loss, from a negative point of view. From the negative point of view these losses have set the baseline for the establishment of regulations which introduced significant responsibilities and liabilities to vessels, owners and operators, ship agents and classification societies, and particularly to countries involved in marine transport. The motive of the countries to act on a joint platform has contributed in the establishment of the international conventions. At this point, the International Maritime Organization (IMO) established committees and prepared a complete set of rules to regulate every aspect of the marine transport (vessel, business, sea, cargo, crew, etc.), to be brought into practice.

International conventions regard the safety of the vessel, vessel crew and its cargo as a whole, aiming to protect the marine environment. Primarily, some of the most important conventions are listed below:

- SOLAS (Safety of Life at Sea) Convention includes rules and regulations for vessel and crew safety;
- MARPOL (Marine Pollution) Convention covers rules and regulations to prevent ship borne pollution;
- Load Line Convention covers rules and regulations to ensure watertight/weather tight integrity of the cargo and vessel;
- COLREG (Collision Regulations) Convention includes regulations on measures taken to prevent collision;
- STCW (Standards of Training, Certification and Watch keeping) Convention covers the rules and regulations relating to the training and standardisation of seamen.

At present, the maritime sector grows at a breakneck speed, with the undeniable effect of technology. There have been rapid increases in the growth of the world trade volume, a simultaneous increase in the world's maritime fleet, and in the tempo of international trade. This in turn has ushered in an era of international competition and complex port operations. However, this fast development also brings forward several handicaps. At this point, it is necessary to clarify "seamen issues," occasionally referred to in this dissertation. Hiring preferences for cheap labour by ship owners and businesses, due to economical concerns, lack of qualified staff to work at the sea and the increased workload due to new rules, result in more work done by less qualified seamen with diligence. This increases the possibility of inefficiency and defects.

The required operational and maintenance rules sustain the vigour for vessels operating in commercially, technologically and environmentally dynamic environments. In addition, new rules and regulations will be added to the already existing substantial set of regulations.

An acute observation of the international rules and regulations that entered into force is another important aspect of it. Establishments that carry out regular inspections of their vessels and types of inspections carried out are as follows:

- ❖ Classification Societies: inspection of the coherence to the standards set by the class society that the vessel is obliged to comply within the framework of international rules, covering the period of operation from the design stage to its demolition;
- ❖ Flag States Controls: inspection of proper operation of vessels liable to own flag state control, in respect to both international and national rules;
- ❖ Port States Controls: inspection by the authorized state, of foreign flag vessels, trading in the territorial water;

- Protection and Indemnity (P&I) Clubs: inspection of the implementation of the mandatory rules for the vessels to protect crew and marine environment and safe transport of the cargo, in terms of insurance.

Numerous rules and different types of inspections brought by these rules currently have an immense pressure on the maritime sector, vessels and on the business aspects.

1.1.1 Tankers in OILPOL and MARPOL Conventions

The IMO entered into force OILPOL 54, followed by MARPOL 73/78 Convention, by extending the OILPOL Convention, to protect the marine environment against ship borne pollution.

The discharge of machinery wastes (bilge & sludge) of ships into the marine environment, although not much in amount, pointed at the need to take precautions to protect the seas. Additionally, the case of TORREY CANYON tanker which ran aground in the English Channel in 1967, causing an environmental disaster with 119,000 tons of crude oil leaking/spreading into British and French coasts, resulted in a change of approach in the international conventions, and the enforcement of stricter rules.

Tankers, carrying chemical cargo, oil and their derivatives play a major role in OILPOL and MARPOL Conventions. Tankers, carrying combustible, flammable and explosive liquid (fluid) derivatives are required to be operated with high safety measures. In spite of all the safety measures taken, tankers still cause marine accidents due to inevitable reasons, such as machinery failures, crew faults and adverse weather/sea conditions. Also tanker accidents indirectly cause environmental disasters. Figure 1.1 illustrates marine accidents occurred between 1978 and 2004, as an example.

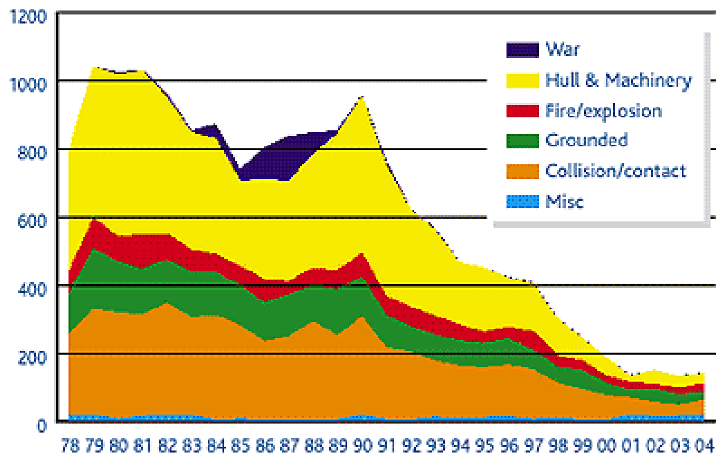


Figure 1.1 Tanker accidents by cause 1978-2004
(Source: INTER-TANKO, 2004)

Figure 1.2 shows the accidents caused by the tankers of different types, built dates and tonnages. In 2004 alone, 140 different tanker accidents have been recorded worldwide. Collision, hull & machinery defects and grounding, have been the main causes.

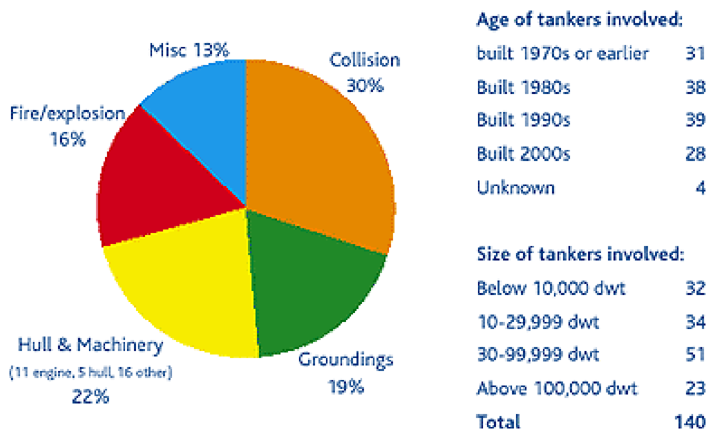


Figure 1.2 Reported tanker accidents in 2004, all sizes/types
(Source:INTERTANKO, 2004)

After each tanker accident causing an environmental disaster, IMO entered into force even stricter rules and conventions. Table 1.1, compiled from IMO (2002) data, presents an overview how the rules have developed chronologically.

Table 1.1 Chronological history of conventions entered into force after marine disasters

In the late 19th century	The world's first oil tankers appeared.
Invention of the motor car (fuel demand).	
During Second World War	Standard size oil tanker "T2", 16.400 DWT (Deadweight tones).
In 1954	The first 100.000 DWT crude-oil tanker was delivered.
The mid-1960s	200.000 DWT tanker has been ordered (VLCC-Very Large Crude Carrier).
The potential for oil to pollute the marine environment was recognized.	
In 1954	International Convention for the Prevention of Pollution of Sea by Oil (OILPOL 1954)
In 1958	The convention establishing IMO entered into force.
In 1965	Subcommittee on Oil Pollution was set up by IMO under the auspices of Maritime Safety Committee.
In 1967	The tanker "TORREY CANYON" ran aground.
IMO called an extraordinary session of its Council .	
In 1969	Amendment of OILPOL Convention was adopted.
In 1969	The IMO Assembly decided to convene an international conference to adopt a completely new convention, which would incorporate the regulations contained in OILPOL 1954 (as amended). The Sub-committee on Oil Pollution was renamed the Sub-committee on Marine Pollution. This became Marine Environment Protection Committee (MEPC).
In 1970	Preparatory meetings of the conference began.
In 1971	Amendment of OILPOL Convention was adopted.
In 1973	International Convention for the Prevention of Pollution from Ships. The conference incorporated much of OILPOL 1954 and its amendments into Annex I, covering oil, while other annexes covered chemicals, harmful substances carried in packaged form, sewage and garbage held.
In 1976	The tanker "ARGO MERCHANT" ran aground.
In 1977	The United States took the lead in asking the IMO Council to consider adopting further regulations on tanker safety.
In 1978	The IMO Council agreed to convene The Conference on Tanker Safety and Pollution Prevention adopted a protocol to the 1973 MARPOL Convention
In 1982	MARPOL 73/78 entered into force.
In 1989	The tanker "EXXON VALDEZ" ran aground.
In 1990	The United States introduce its Oil Pollution Act (OPA 90) making it mandatory for all tankers calling at U.S. ports to have double hulls.
In 1992	MARPOL 73/78 amendment were adopted and entered into force.
In 1999	The tanker "ERIKA" broke in two.
In 2001	The amendments to Regulation 13G in Annex I of MARPOL 73/78 were adopted.
In 2002	Incident of the tanker "PRESTIGE".
In 2003	The MEPC at its 49th session agreed to an extra session of the Committee.
In 2004	The revised MARPOL Annex I Regulations for the prevention of pollution by oil was adopted.
In 2007	The revised MARPOL Annex I Regulations entered into force.

Table 1.2 shows the marine accidents causing the most tragic results, with the data of the International Tanker Owners Pollution Federation Limited-ITOPF.

Table 1.2 Serious tanker accidents

Year	***Name of tanker***	***Type of incident***	***Location***	***Tones of oil spilled***	***Area affected***
1967	Torrey Canyon	Grounding	English Channel	~119.000 tons	French and British Shore
1974	Metula	Grounding	Strait of Magellan, Chile	~50.000 tons	Shores of northern Tierra del Fuego
1976	Argo Merchant	Grounding	Massachusetts	~28.000 tons	Offshore
1978	Amoco Cadiz	Grounding	Brittany coastline	~223.000 tons	Brittany coastline up to Channel Islands
1980	Tanio	Broke in two	Coast of Brittany	~13.500 tons	Breton coasts of Brittany
1983	Castillo de Bellver	Capesize and sank	South Africa	~55.000 tons	Offshore
1989	Exxon Valdez	Grounding	Prince William Sound	~40.000 tons	Hundreds of miles of the Alaskan southern shore
1993	Braer	Grounding	Shetland	~85.000 tons	Shetland
1996	Sea Empress	Grounding	South West Wales	~72.000 tons	Milford Haven and National Park
1999	Erica	Broke in two	Bay of Biscay	~20.000 tons	Shoreline between Finistère and Charente-Maritime
2002	Prestige	Hull damage	Northern Spain	~63.000 tons	Bay of Biscay, the north coast of Spain and the Atlantic coast of France, as far north as Brittany. The French and English coasts of the English Channel and Portuguese waters
2003	Tasman Spirit	Grounding	Karachi Port, Pakistan	~30.000 tons	Clifton Beach, Karachi Port

The data in Table 1.2 indicate that the tanker accidents continued to occur until recently, in spite of all the rules and safety measures taken, and vast amounts of crude oil leaked into the sea and spread to the coastline during each of these accidents.

It has been emphasised from the start of the chapter that the rules of OILPOL and MARPOL conventions are mainly about tankers. Table 1.3 below summarises these rules, to show the importance of tankers.

Table 1.3 Convention items about tankers

OILPOL 54 (The shipboard operations causing pollution)	❖ Dumping of oily wastes within a certain distance form land and in “Special Areas” were prohibited.
1962 Amendment of OILPOL	❖ Limits of the “Special Areas” were extended.
1969 Amendment of OILPOL	❖ “Load on Top” procedure was introduced.
1971 Amendment of OILPOL	❖ The size of cargo tanks in all tankers ordered after 1972 were limited. The intention was that given certain damage to the vessel, only a limited amount of oil could enter the sea.
MARPOL 73 (This incorporated much of OILPOL 1954 and its amendments into Annex I, covering oil, while other annexes covered chemicals, harmful substances carried in packaged form, sewage and garbage)	❖ Continuous monitoring of oily water discharges were required. ❖ To provide shore reception and treatment facilities at oil terminals and ports for Governments are required. ❖ A number of “Special Areas” was established including the Mediterranean, Red Sea and Gulf, and Baltic Seas. The littoral States concerned to provide adequate reception facilities for dirty ballast and other oily residues as implementation were required. ❖ Regulation 13 of Annex I required segregated ballast tanks on new tankers over 70,000 DWT (deadweight tones). To minimize the ballast water to be contaminated by oil carried as cargo or fuel.
MARPOL 73/78 (Tanker Safety and Pollution Prevention-1978) were seen as major steps in raising construction and equipment standards for tankers through more stringent regulations.	❖ The expanded requirements for segregated ballast tanks to all new crude oil tankers of 20,000 DWT and above and all new product carriers of 30,000 DWT and above. ❖ The requirement for segregated ballast tanks to be protectively located. ❖ New tankers over 20,000 DWT were required to be fitted with crude oil washing system. ❖ For existing tankers over 40,000 DWT to be fitted with either segregated ballast tanks or crude oil washing systems; while for an interim period, the Protocol also allowed for some tankers to use clean ballast tanks. ❖ In relation to MARPOL Convention, additional measures for tanker safety were incorporated into the 1978 Protocol to the International Convention for the Safety of Life at Sea (SOLAS), 1974. These included the requirement for inert gas systems on all new tankers over 20,000 DWT and specified existing tankers. The SOLAS Protocol also included requirements for steering gear of tankers; stricter requirements for carrying of radar and collision avoidance aids; and stricter regimes for surveys and certification.

Table 1.3 Continued.

OPA 90 (Oil Pollution Act)	❖ For all tankers calling at U.S. ports were to have double hulls were required.
1992 Amendment of MARPOL 73/78	❖ Double hulls (or an alternative) requirement was contained in Regulation 13F - prevention of oil pollution in the event of collision or stranding. ❖ Regulation 13F applies to new tankers - defined as delivered on or after 6 July 1996 - while existing tankers must comply with the requirements of 13F not later than 30 years after their date of delivery. ❖ Tankers of 5,000 DWT and above must be fitted with double bottoms and wing tanks extending the full depth of the ship's side. The regulation allows mid-deck height tankers with double-sided hulls as an alternative to double hull construction. ❖ Oil tankers of 600 DWT and above but less than 5,000 DWT, must be fitted with double bottom tanks and the capacity of each cargo tank is limited to 700 m^3, unless they are fitted with double hulls. ❖ Regulation 13G, concerned with existing tankers, which makes provision for an enhanced program of inspections to be implemented, particularly for tankers more than five years old. ❖ Regulation 13G also allowed for future acceptance of other structural or operational arrangements - such as hydrostatic balance loading (HBL) - as alternatives to the protective measures in the Regulation.
Revised MARPOL 73/78 (This incorporates the various amendments adopted since MARPOL entered into force in 1983)	❖ The amended regulation 13G (regulation 20 in the revised annex) and regulation 13H (regulation 21 in the revised annex) on the phasing-in of double hull requirements for oil tankers were required. ❖ The construction and equipment provisions from the operational requirements for new ships and those for existing ships were separated. ❖ Regulation 22 Pump-room bottom protection: on oil tankers of 5,000 DWT and above constructed on or after 1 January 2007, the pump-room shall be provided with a double bottom were required. ❖ Regulation 23 Accidental oil outflow performance - applicable to oil tankers delivered on or after [date of entry into force of revised Annex I plus 36 months] 1 January 2010; construction requirements to provide adequate protection against oil pollution in the event of stranding or collision were required. ❖ The Oman Sea area of the Arabian Seas is designated a "Special Area". The other special areas in Annex I are: Mediterranean Sea area; Baltic Sea area; Black Sea area; Red Sea area; "Gulfs" area; Gulf of Aden area; Antarctic area; and North West European Waters.

1.1.2 Tankers as the Main Carrier of a Global Threat

Until recently, tankers have been involved in marine accidents that result in oil originated marine pollution. Therefore they have been regarded as the main source of marine pollution. However, at present, tankers bring about an even greater threat which can overtake the oil-originated marine pollution: the ballast waters.

It is assumed that the oil reserves shall be used until they are exhausted, as long as the new energy sources are not put into effective use. Currently, oil pipelines and large tonnage tankers play a significant role in supplying for the strong oil demand of the countries.

Table 1.4 shows the classification of the tankers, used in world tanker transportation, by their deadweight tonnage and ballast capacities.

Table 1.4 International tanker sizes

	Tonnage (Dwt)	***Ballast Capacity (% of dwt)***
Handy Size	30-50,000	~ 30-38 (IMO, 2004)
Panamax (max. breadth 33,53m.)	50-70,000	
Aframax (Average Freight Rate Assessment)	70-120,000	~ 40-45 (IMO, 2004)
Suezmax (max. draft 16 m.)	120-200,000	
VLCC (Very Large Crude Carrier)	200-300,000	
ULCC (Ultra Large Crude Carrier)	300,000+	~35 (Markovina, Blagojević & Ban, 2007)

Tankers, carrying such large amounts of ballast waters also transfer the marine species within, from one ecosystem to another. Wittenberg & Cock (2001) stated that “the amount of ballast that would be discharged by an average tanker at each voyage is estimated to contain 240 millions of organisms". IMO prepared the International Ballast Water Convention to put into force to “STOP” transfer of marine organisms which recently became a global threat.

1.2 Ballast and Ballast Water

Commercial vessels are designed and built to carry cargo and passengers. Stability and strength calculations are made to provide maximum safety in laden condition. An unloaded ship is exposed to all adverse effects of weather and sea conditions. To provide similar stability and strength conditions as when the vessel is loaded, and to prevent adverse effects of the external forces, it needs to take in loads for balancing. These balancing loads taken onboard is called “ballast.”

The etymology of the word "ballast," meaning "useless load" in the Middle Dutch, reflects the fact that since time immemorial ship owners have endeavored to avoid using ballast (CETS, 1996).

IMO (2004) defined ballast as: “Any material used to weight and/or balance an object. One example is the sandbags carried on conventional hot-air balloons, which can be discarded to lighten the balloon’s load, allowing it to ascend.”

Carlton (1985) and CETS (1996) in their respective articles stated that prior to 1870, vessels used to load chains and other heavy materials such as sand, roof tiles, rocks and beach boulders, instead of ballast water as the balancing load, and noted the most important factors in replacing with seawater as follows:

1. Avoiding time-consuming loading of solid materials,
2. Dangerous vessel instabilities resulting from the shifting of solid ballast during a voyage.

1.2.1 Component of Ballast Water

Ballast water, in a simple explanation, is seawater. Analyzing of the physical, chemical and oceanographic composition of seawater means, to scrutinize the ballast water.

To prevent the introduction of living organisms from one ecosystem to another via ballast water is possible only by destroying these marine organisms during the transfer. At this point, the treatment systems play an important role. The physical, chemical and oceanographic parameters of seawater became determinants in the emergence of the treatment systems, detailed in the third chapter.

Table 1.5 summarises the seawater characteristics in the world seas.

Table 1.5 Sea water characteristics (Wikipedia, 2007)

Salinity	between 3.1% and 3.8% (depending on the evaporation, river flow, runoff from river etc.)
Density of surface water	ranges from 1020 to 1029 kg/m^3 (depending on the temperature and salinity)
pH	limited to range 7.5 to 8.4
Freezing point	-2°C (28.4°F) (decreases with increasing salinity)
Dissolved Gases	Oxygen (O_2) comprises 21% of atmospheric gases, Nitrogen (N_2) comprises 78% of the atmosphere Carbon dioxide (CO_2) comprises 0.03% of the atmosphere. (Breaking waves at the sea surface aerate the water and dissolve atmospheric gases into it)
Nutrients	In the oceans, Carbon, Oxygen, Nitrogen and Phosphorus available in solution as dissolved bicarbonate, phosphate and nitrate.

Some of the ballast water treatment methods developed with the use of seawater characteristics are; destruction of organisms by way of increasing the salinity ratio or the pH level, deoxygenation or heating the seawater in the tank.

Seawater is defined as “a complex solution of dissolved mineral, elements and salts” and it contains all of the known stable elements in various concentrations. Beer (1983) noted that the ratio between various salts is remarkably constant. Table 1.6 shows the ionic composition in seawater.

Table 1.6 Ionic composition (by weight) in seawater

Ion	***Symbol***	***Seawater (%)***
Chloride	Cl^-	55.04
Sodium	Na^+	30.62
Sulphate	SO^{--}_4	7.68
Magnesium	Mg^{++}	3.69
Calcium	Ca^{++}	1.15
Potassium	K^+	1.10
Bicarbonate	HCO^-_3	0.41

(Source: Beer, 1983 p.86)

The world seas have different characteristics. Living organism profiles in seas vary according to different salinity rates, pH degrees, temperatures, current factors and nutrient densities. As of the species living in seawater with high salinity have difficulty in surviving in brackish water environment, also they can adapt to a different form (resting stage) or not able to survive.

Ballast water management plans to be prepared based on these variances of physical, chemical and oceanographic parameters of seawater will play an important role in providing the efficiency and economy in practice.

1.2.2 Why do Vessels Need to Take in Ballast?

Although ballast is a non-commercial load, it is an important factor for the vessels. When the vessels are not in laden condition, they take in ballast;

- ❖ to ensure safety of the voyage, by providing similar stability and strength values of laden condition,

- ❖ to ensure that vessel sit deeply enough in the water to enable efficient and effective operation of their propellers,
- ❖ to increase the draft and change the trim to regulate the stability,
- ❖ to maintain stress loads within acceptable limits,
- ❖ to ensure the structural integrity,
- ❖ to ensure that the vessel stays upright

1.2.3 Location of the Ballast Water in the Hull

Ballast water is taken into the ballast tanks, via its own ballast line, through the sea chests located in the hull. Figure 1.3 illustrates the structure of the sea chest and various locations.

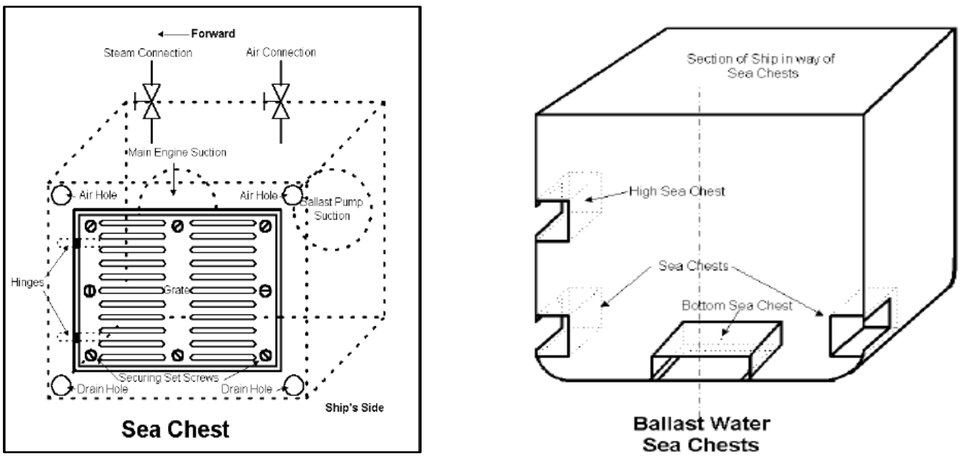


Figure 1.3 Basic design and various location of sea chest
(Source: Taylor & Rigby, 2001, pp.28-29)

Currently, vessels have special tanks for the ballast. Locations and shapes of these tanks vary according to vessel types. In many vessels, double-bottom tanks, side tanks, fore-peak and aft-peak tanks, hooper tanks and wing tanks are used as the ballast tank. In some exceptional cases, vessels can also take in ballast water in their cargo spaces (holds or cargo tanks). Table 1.7 shows the tanks used as the ballast tanks in different types of vessels and Figures 1.4, 1.5 and 1.6 show the location of the ballast tanks.

Table 1.7 Tanks used to take ballast in various types of the vessel.

Type of the Vessel	***Tanks Used For Ballast***
Bulk Carrier	Top-side tanks, Double-bottom tanks, Fore Peak and Aft Peak tanks, Double Hull Side Tanks (current regulation)
Crude Oil Carrier	Double Hull Side Tanks (current regulation), Fore Peak and Aft Peak Tanks
Container Vessel	Double Bottom Tanks and Side Tanks, Fore Peak and Aft Peak Tank, Heeling Tanks
General Cargo Vessel	Double Bottom Tanks, Fore Peak and Aft Peak Tanks
Ro-ro Vessel / Passenger Ferry	Double Bottom Tanks, Fore Peak and Aft Peak Tanks, Heeling Tanks
Passenger	Double Bottom Tanks, Fore Peak and Aft Peak Tanks, Heeling Tanks

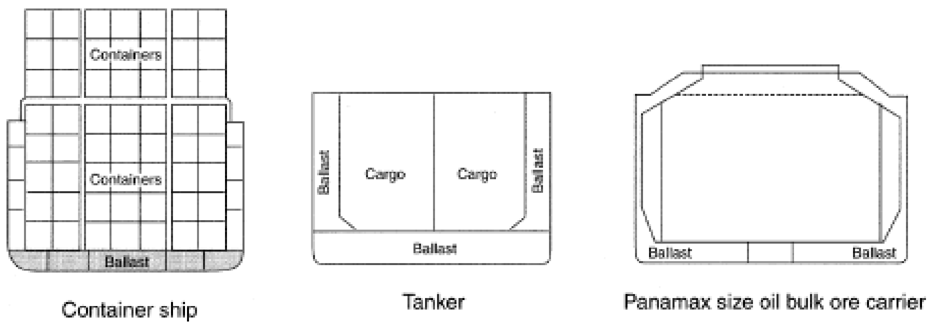


Figure 1.4 Mid-section views of different types of ship, showing the ballast tank arrangements (Oemcke, 1999, p.10)

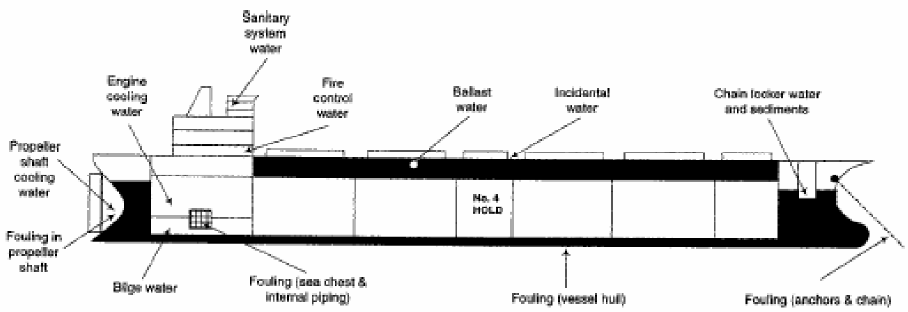


Figure 1.5 Layout of ballast tanks
(Oemke, 1999, p.8)

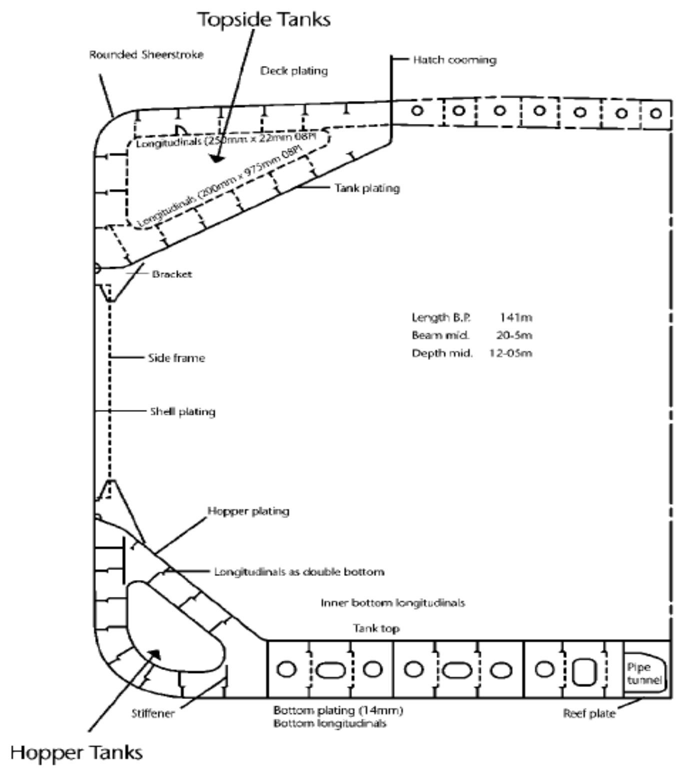


Figure 1.6 Midship section of a handysize bulk carrier fitted with separate topside tanks; double bottom and side hopper tanks are combined. (Source: Oemcke, 1999, p.9)

The location of ballast tanks in tankers is specified as the side tanks with consecutive rules in 1992 Amendment of MARPOL 73/78. According to these rules, tankers shall be built/modified as double-hull (ship in ship) and shall only take ballast into the side tanks (Figure 1.7). There are two main reasons why this costly process is mandatory. Taking ballast into the unloaded cargo tanks allowed dispersion of the cargo residuals into the ballast and caused dirty ballast discharge at the destination port. Thus the extent of the possible pollution would be drastic, considering the number of the tankers in the world. Another reason was to prevent environmental disasters, caused by tanker accidents. According to this regulation, in case of the accidents of the double hull tankers, it is projected to prevent excessive oil leakage by absorbing impacts on the outer skin and thus minimizing/avoiding damage on the inner skin.

Figure 1.7 illustrates the conversion of originally built as single hull tanker M/T "Palva", into the double hull form, by undergoing a major conversion, after the double hull regulation has entered into force. The highlighted parts show the location of the segregated ballast tanks.

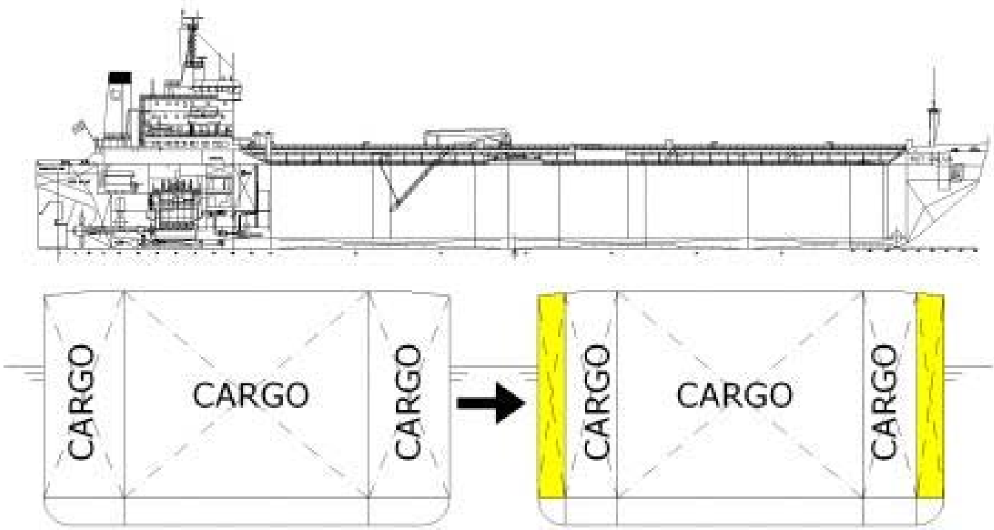


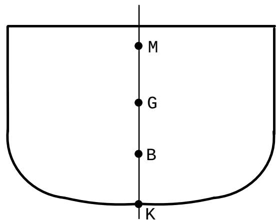
Figure 1.7 Single and double hull version of M/T Palva
(Source: Foreship, 2005)

1.3 Role of Ballast for the Vessel Stability

Engineering rules/calculations should always be based on the probability of the combinations of the hardest conditions. These rules are also applicable to vessels designs. Therefore, vessels are designed, built and equipped to be capable of staying in stable condition and floating upright, even in the most adverse conditions caused by the weather, sea or the cargo on board.

BIMCO (2003) stated the following simple comment to explain the vessel stability: "A ship, if she is not to sink, must remain buoyant, but if she is to float the right way up, must also have the vital quality of positive stability."

To scrutinize the vessel stability, it is necessary to briefly analyse the "Buoyancy Law" of Archimedes. According to Archimedes Law, a solid object floating in liquid is pushed upwards with a contrary force which is equal to the weight of the fluid that overflows. If these two forces are equal to each other, the object will not sink, the two forces will balance each other and the object will float. These two forces impacting on the stability are the buoyancy and the weight. As long as the buoyancy is greater than the weight, the vessel will float. Figure 1.8 shows the locations of the centers of these two forces on the hull.



M – Metacenter
G - Center of Gravity
B - Center of Buoyancy
K – Keel (base line reference point)

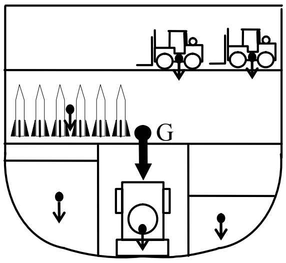
Figure 1.8 Stability reference point
(Source: SWOSC, 2000)

In a stable vessel, the center of gravity (G) is above the center of buoyancy (B). The forces acting vertically on the vessel from these centers are in opposite direction and are equal to each other. In order for the vessel to float vertically upright, these two centers must be located on the centerline of the vessel.

1.3.1 Center of Gravity

The weight of a vessel consists of the entire weight of the loaded cargo, the fuel/fresh water in the tanks, ballast if exists and constants, as well as its own light weight.

The center of gravity is the common intersection point where the vertical forces that constitute the weight of the vessel (Figure 1.9). Akın (2000) defines the center of gravity as "the center of the vessel mass." In the center of gravity, there is an estimated force that pulls the floating vessel downwards vertically. This force is equal to the weight of the vessel and is referred to as displacement (Δ).



- "G" moves towards a weight addition
- "G" moves away from a weight removal
- "G" moves in the same direction as a weight shift

Figure 1.9 Center of Gravity
(Source: SWOSC, 2000)

When a vessel, floating upright, inclines to one side when it is exposed to any external force, such as wind or waves, and the load of the vessel is not shifted, the center of gravity remains at the same point. However, when the load is shifted, then the vessel's center of gravity also shifts in the direction of the load movement. Since ballast is also a type of weight, it will change the location of the vessel's center of gravity, depending on the location of the tank. This is why the ballast operations must be carried out carefully and after concise calculations. Inaccurate operation of the ballast water will have negative impacts on the center of gravity and on the center of buoyancy, and can cause the vessel to capsize. Also, other important factors to be considered in the ballast operations are shearing force and the bending moment on the hull.

1.3.2 Center of Buoyancy

Center of buoyancy is defined as the geometrical center of the underwater structure of a vessel (Figure 1.10). The vessel is pushed from this center upwards vertically, with the composite force of the buoyancy. According to the main rules of physics, a vessel wider in breadth is always more stable than a vessel narrow in breadth and a vessel deep in draft is always more stable than a vessel less deeper in draft thus, indicating the significance of the vessel's underwater form.

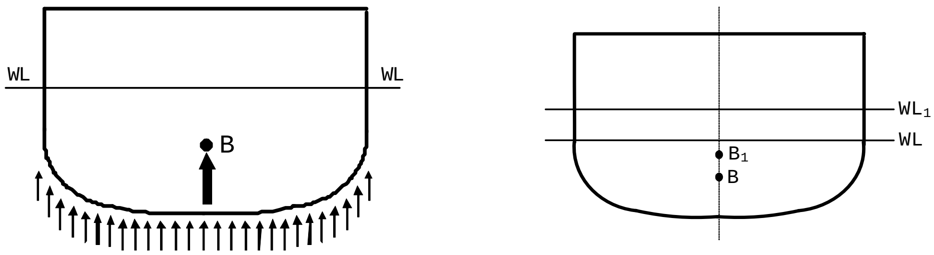


Figure 1.10 Location of the center of buoyancy and its shift according to the water line
(Source: SWOSC, 2000)

When the vessel rolls to the sides with the influence of external factors, the center of buoyancy of the vessel will shift as follows:

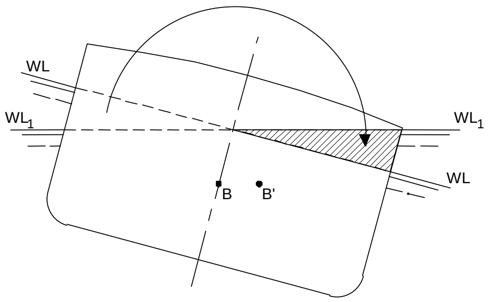


Figure 1.11 Shift of the center of buoyancy with the tilt of the vessel
(Source: SWOSC, 2000)

When a ship is inclined, the center of buoyancy shifts off the centerline while the center of gravity remains in the same location. Since the forces of buoyancy and gravity are equal and act along parallel lines, but in opposite directions, a rotational movement is developed. This is called a couple, two movements acting simultaneously to produce rotation (Figure 1.12). This rotation returns the ship to where the forces of buoyancy and gravity balance out (SWOSC, 2000).

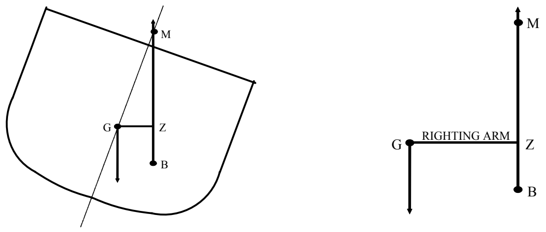


Figure 1.12 Moment created by the forces acting on the vessel
(Source: SWOSC, 2000)

GZ distance is assumed to be the righting arm of the vessel. The forces of the center of gravity and the center of buoyancy act on the G and Z points at each end of this arm, creating moment on the hull. The created moment moves the vessel upright, to the original vertical position.

Apart from external factors, improper operations on the vessel can also cause a shift in the center of buoyancy. As of, improper "ballast exchange" operation may shift the center of buoyancy, influencing the vessel stability negatively, thus proves the significance of the center of buoyancy.

1.3.3 Stability Conditions

Positive Stability (Stable Equilibrium)

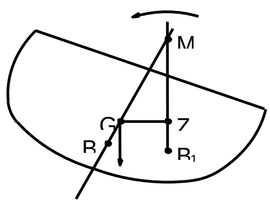


Figure 1.13 Positive stability condition
(Source: SWOSC, 2000)

As the ship is inclined, Righting Arms are created which tend to return the ship to its original, vertical upright position. GM is positive. G point is below M point. GZ arm is on the inclined side. After each rolling, Righting Arm acts on the vessel to bring the vessel upright again i.e.

Neutral Stability (Neutral Equilibrium)

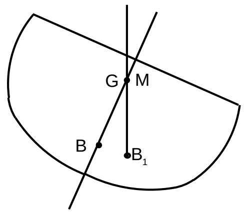


Figure 1.14 Neutral stability condition
(Source: SWOSC, 2000)

As the ship is inclined no Righting Arms are created (Until the metacenter starts to move after the ship is inclined past 7o-10o). GM is zero. G point intersects with M point. GZ value is zero. Because the vessel cannot create a force against the inclining force, it cannot reach to an equilibrium. It can not return back to her original vertical upright position i.e.

Negative Stability (Unstable Equilibrium)

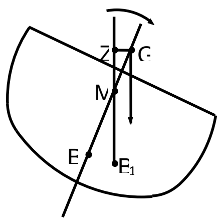


Figure 1.15 Negative stability condition
(Source: SWOSC, 2000)

As the ship is inclined, negative Righting Arms (called upsetting arms) are created which tend to capsize the ship. GM is negative. G point is above M point. GZ arm is on the opposite side of the inclination. Particularly in the vessels, loaded with timbre/wood on the deck, when rain/seawater saturates cargo, the center of gravity moves upwards above the metacenter point. In this case, the vessel will be capsized i.e.

Stability is maintained by moving water around the vessel's ballast tanks, to ensure that the ship stays upright, and does not adopt a heel to one side or the other if the cargo is loaded asymmetrically, or if fuel is taken from a tank on one side of the ship. Water ballast is frequently carried to maintain stability in an otherwise empty ship. In a cargo ship loading in several ports for discharge in several others, after a long sea passage, the stability has to be computed for all stages of the voyage so that there is adequate stability at all times, even with the variable tonnage of cargo and after nearly all the fuel and other consumables have been used up as the end of the voyage approaches. Large amounts of deck cargo or heavy lifts could adversely affect the stability and would require to be compensated with extra ballast. (BIMCO, 2003)

1.3.4 Free Surface Effect

It has been mentioned that the vessel must be constantly in balance both against external and internal factors. An internal factor that should be considered for the vessel stability is the “free surface effect.”

Vessels can carry cargoes loaded in proper stability condition as long as they are properly secured (with lashing equipments or other securing devices etc.). However, liquid cargoes have no particular securing methods. When the tanks are partially filled with liquid cargoes, it poses a risk for the vessel. In this case, free surface effect occurs. Marine Safety Directorate Transport Canada-MSDTC (2004) and Surface Warfare Officers School Command-SWOSC (2000), define the free surface effect as follows:

When a vessel with full tanks heels over, the tank’s center of gravity does not change, so it does not affect the vessel’s stability. Liquid that only partially fills a compartment is said to have a free surface that tends to remain horizontal (parallel to the waterline). When the ship is inclined, the liquid flows to the lower side (in the direction of inclination), increasing the inclining moment. When this happens, the center of gravity also shifts, making the vessel less stable. This "free surface effect" reduces stability and increases the danger of capsizing (MSDTC, 2004 & SWOSC, 2000).

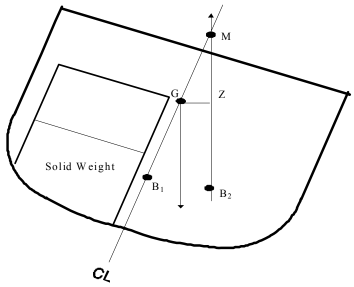


Figure 1.16 Inclination with solid weight
(Source: SWOSC, 2000)

If the tank contains a solid weight, and the ship is inclined, the center of buoyancy shifts in the direction of the inclination and righting arms (GZ) are formed.

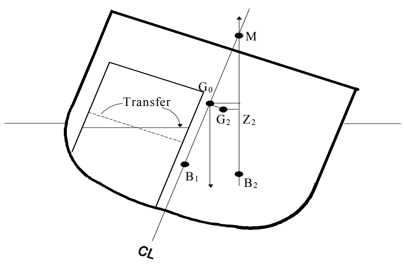


Figure 1.17 Free surface effect
(Source: SWOSC, 2000)

Replacing the solid with a liquid of the same weight; when the ship is inclined, the surface of the liquid remains horizontal. This results in a transfer of "a wedge of water," which is equivalent to a horizontal shift of weight, causing gravity to shift from G_0 to G_2.

Ballast water is considered to be a non-commercial liquid cargo and the amount onboard is important. In order to avoid the free surface effect, the vessels take in seawater entirely into ballast tanks that are specified for that voyage. The implementation of the sequential method, which is one of the ballast water exchange method is a risky operation where the free surface effect should be taken into consideration. In the sequential method, the tanks are emptied and refilled in a specific order. Because free surface effect will occur in the ballast tanks during the operation, in adverse weather/sea conditions, preparation of an appropriate ballasting plan has vital importance for the stability and strength of the vessel. Annex II indicates an example of a sequential method, taken from a Ballast Water Management Plan of a vessel.

CHAPTER TWO
MARINE ENVIRONMENT

Chapter 1.2.3 discusses that the ballast water is taken into the ballast tanks of the vessels through the sea chests. Grates or screens over the sea chest may prevent large organisms from being entering in the ballast tanks, however, even larger species such as adult crabs and fish have been found inside sea chests. According to the research conducted in the University of California Agriculture and Natural Resources (2008), the list of marine species found inside ships' sea chests includes sponges, sea anemones, hydroids, worms, sea slugs, mussels, oysters, scallops, bryozoans, barnacles, crabs, sea stars, sea urchins, sea squirts and fish. This shows that all types of organisms, eggs, organisms in resting stage, cycts and living organisms in other forms of a limited size can easily enter in the sea chest, pass through the ballast pumps and penetrate into the ballast tank.

Dobbs and Rogerson (2005) stated that the quantity of the organisms the seawater contains: "In lakes and oceans, every milliliter of water contains about 10^2 protists (single-celled eukaryotes), 10^6 bacteria, and 10^7-10^9 viruses. Therefore billions of organisms inevitably enter ships' ballast tanks during operations." This is also supported by the statement of Wittenberg and Cock (2001) that "the amount of ballast that would be discharged by an average tanker at each voyage is estimated to contain 240 millions of organisms" which is also referred to in Chapter 1.1.2.

Then broad scale of biological diversity, particularly in the coastal areas enables the intake of these living organisms into the vessel via ballasting. This concentrated living organism mixture taken into the ship's ballast tank can be referred to as an "organism cocktail." The living organisms in this cocktail will be able to survive, as long as they find the suitable conditions inside the ballast tank. Waite et.al, (2003) mentioned that "several planktonic species survived a 23-day-voyage from Singapore to Bremerhaven in Germany and it was also noted that harpacticoid copepods actually increased in abundance by a factor of 100 during the voyage.”

However, under some circumstances, the conditions in the tank may not be suitable for living organisms:

1. Vessels may have to keep ballast in their tanks for a very long period of time, from some hours to some months, due to the time and distance of voyages. However, the characteristics of the seawater inside the tank can alter in long-term during voyages. Elimination of the light factor in the environment may lower the chance of certain photosensitive organisms to survive. In addition, the gradual depletion of oxygen and food stocks in the environment over time initiates a struggle among the organisms for survival. Since this situation results in the death of the majority of living organisms within the tank, it has been taken into consideration by some scientists who have conducted studies on it. (The studies concerning this situation are shown in Table 2.7.)

2. Ships may retain ballast in some of their tanks (especially in aft-peak and fore-peak tanks) constantly, due to the reasons referred to in Chapter 1.2.2. The ballast water, which are not included in any ballast operation and remain in the ship constantly, became old and aged in time. Due to the alteration of the characteristics of the aged ballast water, those living organisms in the tank which cannot adapt to the environment, die.

Studies point out that certain organisms can adapt to environments where oxygen is depleted, due to their resistance to lack of oxygen. This is also true for organisms which are resistant to heat and salinity. Therefore this shows that ballast water treatment systems cannot be fully-functional for every type of marine species.

Reason stated above, shows the need for extensive studies on the living organisms in the marine environment which shall enable the preparation of management plans for minimising the damages that may be caused by living organisms, transferred with ballast.

2.1 Marine Organisms

Approximately 71% of the globe is covered with oceans. This immense water mass is the "home" of millions of species, from protozoa, the smallest species, to the largest mammal.

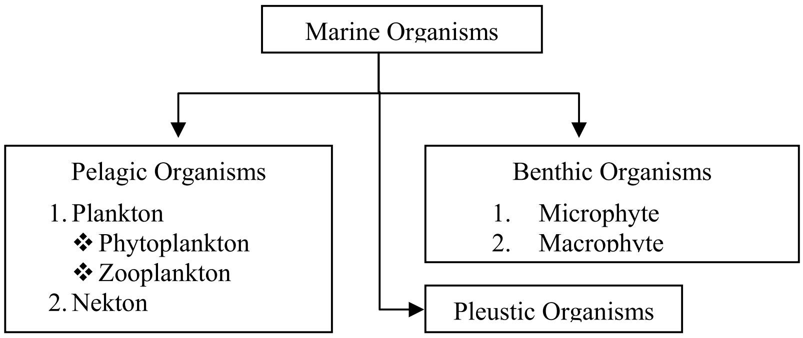


Figure 2.1 Category of the marine species.

Marine organisms can be placed in three categories depending on where they live. These are:

1. Pelagic organisms that live on the water mass,
2. Benthic organisms that live on or in the bottom sediments or rock,
3. Pleustic organisms that straddle the air-water interface.

These categories are by no means mutually exclusive or rigidly definable. For example, some species are benthic as adults but pelagic as larvae, and a number of pelagic organisms may spend much time resting on or feeding at the sediment-water interface. (Barnes & Hughes, 2000)

2.1.1 Pelagic Organisms

Pelagic ecosystems cover more than 70% of the surface of the earth. Their species' diversity and richness are related to physicochemical and biological processes acting at a range of temporal and spatial scales. They are strongly influenced by atmosphere–ocean (coupling) interactions related to hydrodynamic processes (Belgrano, Batten & Reid, 2001).

2.1.1.1 Plankton

Plankton, in a large size range between 0.02µm and 200cm, are free-floating organisms which are limited in movement in spite of having movement organelles, and can change place by currents. They are everywhere in the hydrosphere, which covers ¾th of the earth (Table 2.1). Özel (2007) points at the fact that no other group of organisms other than plankton has a habitat of such a huge scale.

Table 2.1Classification of plankton by size

Size Category	***Size Range***
Megaplankton (jellyfish, ctenophores etc.)	20-200 cm
Macroplankton (medusae, pteropods etc.)	2-20 cm
Mesoplankton (copepods, heteropoda etc.)	0.2-20 mm
Microplankton (diatoms and dinoflagellates etc.)	20-200µm
Nanoplankton (diatoms, coccolithophores, and silicoflagellates etc.)	2-20 µm
Picoplankton (bacteria etc.)	0.2-2 µm
Femtoplanton (marine viruses)	0.02-0.2 µm

Source: Kennish (2001.p.444)

Plankton can be examined under two groups:

- Phytoplankton (that are capable of partially synthesizing their own materials by photosynthesis, i.e. autotroph),

- ❖ Zooplankton (that feed on organic particles and/or organisms in the environment, i.e. heterotroph).

Phytoplankton

Kennish (2001) defines phytoplankton as follows: “The principal primary producer of the world’s oceans are microscopic, free-floating plants, which inhabit surface waters, including those under ice in polar seas. These unicellular, filamentous, or chain-forming species encompass a wide diversity of photosynthetic organisms.”

“Taxonomic groups of plankton include diatoms, dinoflagellates, coccolithophores, and silicoflagellates. In estuaries, lagoons, and coastal embayments other taxonomic groups may locally predominate, such as euglenoid flagellates, green algae, blue-green algae, and brown-colored phytoflagellates”. (Kennish, 2001)

Zooplankton

Zooplankton are the heterotrophic type of plankton and also secondary producers in pelagic ecosystems. It can be divided into two major categories:

- ❖ holoplankton, which are organisms that spend their entire lives as plankton,
- ❖ meroplankton, which are organisms that spend part of their life cycle as plankton and part on the seafloor as benthic invertebrate larvae or as nekton (e.g., fish larvae).

Zooplankton comprise an extraordinarily wide range of organisms includes both small protozoans (a unicellular heterotrophic protist) and large metazoans (a major group of multicellular, eukaryotic organisms). This wide phylogenetic range includes a similarly wide range in feeding behavior: filter feeding, predation and symbiosis with autotraophic phytoplankton as seen in corals. Zooplankton feed on bacterioplankton, phytoplankton, other zooplankton (sometimes cannibalistically), detritus (or marine snow) and even nektonic organisms (Wikipedia, 2008a).

Table 2.2 Characteristics of dominant planktonic organisms in the sea

Type	*Structure*	*Typical Size (μm)*	*Skeletal Material*	*Where Dominant*	*Remarks*
Bacteria	Microscopic, unicellular organisms	<5	None	Sediments and surfaces. Surface waters only	Bacteria attain peak numbers in estuarine waters (~10^6 to 10^8 cells/ml), and in the coastal ocean (1 to 3×10^6 cells/ml)
Producers (plants)					
Blue-green algae	Include unicellular and colonial species	5	None	Nowhere, but tend to grow on surfaces	Most are found in fresh water, while others are marine, occur in damp soil, or even temporarily moistened rocks in deserts (Wikipedia, 2008c)
Coccolithophores	Unicellular, flagellated algae	3-10	Calcium carbonate	Warm open ocean (Tropical and Subtropical)	Highest abundances occur in subtropical and tropical waters, although a few species reach peak numbers in colder regions.
Silicoflagellates	Unicellular, uniflagellate organisms	5-40	Silica	Cool open ocean (polar and subpolar)	Although found in seafloor sediments of all the major ocean basins, silicoflagellates are most numerous in cold, nutrient-rich regions.
Diatoms	Unicellular organisms	20-80	Silica	Cool, nutrient rich (upwelling, polar and coastal)	Highly productive, diminutive plants. Diatoms occur as single cells or chains of cells floating in the water column or attached to the surface. They can exist as colonies.
Dinoflagellates	Unicellular, biflagellated planktonic algae	10-50	Cellulose or none	Warm quiet waters, wherever the others are scarce	Dinoflagellate blooms exceeding 10^6cells/l commonly develop in estuaries and coastal lagoons during the warmer months of the year. Some dinoflagellates produce neurotoxins. (Toxic red-tide)
Consumers (animals)					
Radiolarians		50-500	Silica	Surface waters and sediments	They are found as zooplankton throughout the ocean, and their skeletal remains cover large portions of the ocean bottom as radiolarian ooze (Wikipedia, 2008c)
Foraminifera		100-1000	Calcium carbonate	Surface waters and sediments	Modern forams are primarily marine, although they can survive in brackish conditions. A few species survive in fresh water (Wikipedia, 2008c)

Kennish (2001) made a classification of zooplankton sizes, by conducting measurements with a plankton net of 202µm mesh size. Accordingly, zooplankton forms that pass through the plankton net constitute the nanozooplankton and microzooplankton, and those forms retained by the net comprise the mesozooplankton.

Table 2.2 presents information on the characteristics of dominant planktonic organisms, as an extension of the table of Kennish (2001).

2.1.1.2 Nekton

Nekton refers to the aggregate of actively swimming aquatic organisms in a body of water (usually oceans or lakes) able to move independently of water currents. Nekton are contrasted with 'plankton' which refers to the aggregate of passively floating, drifting, or somewhat motile organisms occurring in a body of water, primarily comprising tiny algae and bacteria, small eggs and larvae of marine organisms, and protozoa and other minute predators. (Wikipedia, 2008b)

2.1.2 Benthic Organisms

Benthic (bottom-dwelling) organisms can be categorized by Snelgrove (2001), dependent on where they live.

- Hyperbenthos are organisms which may reside just above the bottom but closely associated with it,
- Epifauna are organisms which may reside on the sediment surface,
- Infauna are organisms which may reside among the sediment grains.

The benthic flora is subdivided into microphyte and macrophyte components. The microphytes (or microscopic plants) consist of diatoms, dinoflagellates, and blue-green algae. They commonly inhabit mudflats and sand flats in intertidal habitats, growing on sediment grains or forming mats on sediment surfaces. (Kennish, 2001)

Table 2.3 Classification of benthos by size

Benthos	***Size Range***
Macrobenthos (crustaceans, corals, sponges etc.)	Greater than 1 mm
Meiobenthos (foraminiferans, copepods etc.)	32 µm - 1 mm
Microbenthos (bacteria, diatoms, ciliates etc.)	Less than 32 µm

2.2 Importance of Resting Stage

Marine organisms change form to be able to survive in unsuitable environmental conditions. This life stage, called the resting stage, is when the organisms are the strongest and most resistant to external factors. The transfer of this extremely resistant form via ballast waters from one point to another and that they revert to their original forms and reproduce in suitable environmental conditions has been one of the most significant topics referred to by scientists in their research. The important point about the resting stage, compiled from the research of Doblin et.al. (2001) are presented below.

- Resting stages are life cycle stages produced by invertebrate, phytoplankton, protozoan and bacterial species at high frequency when environmental conditions deteriorate (e.g. declining nutrient concentrations, photoperiod, or food quality, such as might be found in a ballast tank several days after filling).

- Resting stage production ensures long-term viability of a population because of their extreme resistance to adverse conditions, including anoxia, noxious chemicals, freezing, and passage through digestive tracts of fish and waterfowl.

- ❖ Invertebrate resting eggs and dinoflagellate cysts are usually negatively buoyant and sink when released or when the organism that produced them dies.

- ❖ Resting stages may remain viable in sediments in a virtual suspended metabolic state for decades or even centuries and can germinate under a combination of favorable light, temperature and other environmental conditions.

2.3 Productivity of Coastal and Ocean Environment

Primary producers compound the most important loop of the food chain. Light and nutrients (nitrogen and phosphorus) are the primary factors that limit primary production in the ocean.

Coastal areas are the places where the diversity of species is the richest because of fresh water input (rivers, etc.). Especially areas near the equator and midtemperate latitudes, where the light penetrates in depth, the temperature is high and the nutrient input is abundant, are the most productive areas for primary production.

Upwelling zones constitute another dimension of the primary production. In many coastal areas where a combination of wind and currents moves the surface water away and allows the cold, deep water to move up to the surface, in general, a superabundance of nitrogen and phosphorus is available to the phytoplankton. Grassle (2001) indicated in his research that upwelling zones contribute approximately 18% to the net ocean primary productivity. Table 2.3 shows a comparison of primary production.

Table 2.3 Comparison of primary production for coastal ecosystems

	g C/m²/year
Coastal waters	
Ocean waters	5-50
Upwelling zones	50-220
Shallow shelf	30-150
Coastal bays	50-120
Surf zone	20-30

Source: (Kennish, 2001)

While some of anthropogenic factors destroy the coastal and marine environment (Figure 2.2), some result in primary production, due to intense nutrient input. Some of the factors causing primary production are: direct discharge of effluents and solid wastes into the seas and oceans, land runoff into the coastal zone, increase in the global inputs of nitrogenous fertilizers, the mining of phosphate rock, and etc. These types of factors result in an increased primary production, i.e. euthrophication, due to providing an excessive amount of nutrient input to the marine ecosystem. Grassle (2001) points out in his research that when algal production is above 300g $C/m^2/y$, there will be euthrophication. Thus, this will cause anoxia in the ecosystem, which will destroy the habitats of fish and other organisms.

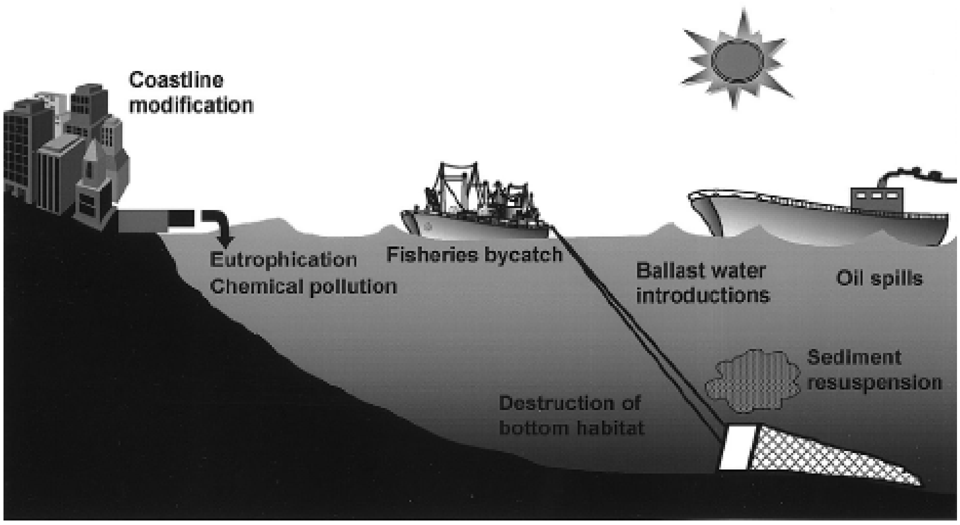


Figure 2.2 Schematic presentations of some of the anthropogenic factors threatening marine organisms
(Source: Snelgrove, 2001)

2.4 Marine Invasive Species / Non-native Species / Exotic Species

The diversification, strengthening and speeding of the transport net all over the world facilitated the transport of people and vehicles from one place to the other. Hence, the organisms accompanying people and vehicles were carried, as Buck (2005) has appropriately expressed as “hitchhikers.” Some of these hitchhiker organisms became invasive in the environments where they have penetrated.

The introduction of exotic species has long been recognized as a serious environmental problem. The introduction of rabbit to Australia and of Dutch elm disease to North America are two noticeable examples. While the invasion of exotic terrestrial organisms have been widely studied, extensive attention has not been paid to the invasion of aquatic organisms until the introduction of zebra mussels to the Great Lakes and of toxic dinoflagellates to Australia, both of which have resulted in great economic loss. (Chu, Tam, Fung & Chen, 1997)

At present, the ballast tanks of the vessels play an important role in carrying marine organisms from one point to another. With the discharge of the ship’s ballast water in the destination port, the marine organisms enter into a new environment. Those organisms that cannot adapt, die those that are able to adapt, survive. Among the adapted living organisms, those which are able to get the chance to feed and reproduce will pose a threat to the new environment where they have no predator and shall become invasive. Table 2.4 provides detailed information on the marine species that became invasive in the ecosystems where they have entered and caused the most severe damages.

Table 2.4 Some well-known exotic species that devastate the ecosystems.

Exotic Species	***Suspected Origin***	***Observed Place & Time***	***Details***
American Comb Jelly *(Mnemiopsis Leidyi)*	Atlantic Ocean	Black Sea & Azov Sea in late 1980s	There took place one of the most devastating biological explosions ever recorded by science. The comb jelly is-an animal with no known predators to control it, voracious predator on zooplankton and fish eggs and larvae has been largely responsible for the collapse of the anchovy fishing industry in the Black Sea. In the Sea of Azov, Mnemniopsis consumed almost the entire zooplankton population, which in 1989 and 1991 collapsed to one-six-hundredth of its normal average. (IMO, 1999)
Tropical Green Algae *(Caulerpa Taxifolia)*	Australia, Brazil, Ceylon, Indonesia, Philippines, Tanzania & Vietnam	Mediterranean Sea in 1984	It is marine green macroalgae. In the Mediterranean, *Caulerpa taxifolia* invades the dominant seagrass, *Posidonia oceanica*, and in invaded areas able to kill up to 45% of *Posidonia* shoots in one year and limits the natural habitat for larval fish and invertebrates. (IMO, 1999 & UF/IFAS, 2007)
Asian Clam *(Potamocorbula Amurensis)*	Japan, Korea and China to about 22°N latitude.	San Francisco Estuary 1984-1988	It is highly efficient filter-feeder, ingesting bacteria and small zooplankton as well as phytoplankton. It accumulates selenium in its tissues, thereby making this contaminant available to the fish and birds that feed on Potamocorbula at concentrations that seem likely to impair reproduction. (Cohen, 1998)
Zebra Mussel *(Dreissena Polymorpha)*	Caspian Sea & Black Sea	Great Lake in 1985	The mussels were noticed when they reached densities of 750,000 per m2 in water pipes in Lake Erie, clogging the water intakes of city water systems, electrical power stations, and other industrial facilities and fouling boat hulls and accumulating in immense numbers on recreational beaches in the Great Lakes. They depress populations of zooplankton. In the Hudson River in NY, phytoplankton biomass wars reduced 80-90% after zebra mussels invaded, and zooplankton that feed on phytoplankton declined by more than 70% after the invasion. (Cohen, 1998 & Krebs, 2001)
Northern Pacific Seastar *(Asterias Amurensis)*	Japanese & Alaskan Waters	Tasmania, Australia 1986	The seastar has virtually wiped out a species of shellfish and is a major threat to the marine environment. It is also adversely affecting the Tasmanian fisheries. (INTERTANKO, 2002)
Toxic Dinoflagellate *(Gymnodinium Catenatum)*	Japan, Argentina, Mediterranean Seas	Australian Waters in 1990	Toxic dinoflagellates are a type of algae known to cause paralytic shellfish poisoning in humans. These microscopic organisms can become phenomenally abundant, producing discoloration of the sea known as red tides. Red tides may kill fish or invertebrates by clogging their gills, and some produce human neurotoxins that accumulate in clams or mussels, sickening and sometimes killing the people that eat them. They can reproduce simply by splitting in two, allowing multiplication wherever conditions are favorable. (IMO, 1999 & Cohen, 1998)

Introduction of invasive species in its new environment can cause a range of impacts. Various impacts that Raaymakers (2002), Ambrogi (2001) and Cohen (1997) have determined are harmonised and presented in Table 2.5.

Table 2.5 Effects of marine invasive species

Effects on Marine Ecosystem	***Effects on Human Activities***
❖ Competing with native species for resources (space, food, spawning area etc.),	❖ Physical impacts on coastal infrastructure, facilities and industry, especially by fouling species.
❖ Preying upon native species	❖ Fouling of boats and marine structures
❖ Changes in productivity	❖ Boring of wooden boats and structures
❖ Changes in trophic pathways	❖ Fouling of waterways and water systems
❖ Changes in nutrient or contaminant cycling	❖ Reduction in the economy and efficiency of shipping due to fouling species
❖ Changes in habitat (Ecosystem instability)	❖ New human parasites or diseases
❖ Altering environmental conditions (e.g. increased water clarity due to mass filter-feeding)	❖ Costs of maintaining facilities and services against fouling and other damages
❖ Introduction of new functional groups or guilds	❖ Costs of monitoring, intercepting and controlling exotic species
❖ Reducing native biodiversity and even causing local extinctions	❖ Reductions in fisheries production
❖ Introduction of potentially toxic species (algal blooms producing harmful toxins in some seafood)	❖ Impacts and even closure of recreational and tourism beaches and other coastal amenity sites due to invasive species (e.g. physical fouling of beaches and severe odours from harmful algae blooms).
❖ Increase in local species number	❖ Changes in populations that support existing fisheries
❖ Genetic effects on native species	❖ New fisheries
❖ Altering the food web	❖ Impacts on aquaculture especially from introduced harmful algae blooms.
❖ Introduction of new disease agents or parasites (viruses, bacteria, fungi etc.). The non-native host species might be slightly affected, but native species are not immune	❖ Secondary economic impacts from human health impacts of introduced pathogens and toxic species, including increased monitoring, testing, diagnostic and treatment costs, and loss of social productivity due to illness and even death in affected persons.
❖ Loss of genetic diversity	❖ Secondary economic impacts from ecological impacts and bio-diversity loss
❖ Introduction of a species being a missing link as host in the life cycle of a parasite	❖ Costs of responding to the problem (research and development, monitoring, education, communication, regulation, compliance, management, mitigation and control costs)
❖ Loss of geographic diversity	❖ Pollution from herbicides, pesticides and anti-fouling compounds

Until today, many scientists have conducted research on the living organisms that are carried by ballast tanks. Table 2.6 shows some examples of the marine species included in the seawater that is taken into the tanks of ships during ballast operations.

Table 2.6 Investigations of ballast tank biota

Study	***Site and Period***	***Sampling Regime and Results***
1	Australia 1973	Plankton sampled in 1 ship from Japan included polychaetes, copepods, amphipods, ostracods and vhaetognaths
2	Australia 1976-78	Plankton and fish in 23 woodchip carriers from 13 Japanese ports included 61 species; most common were copepods, mollusks, larvaceans and barnacles. Sediments from 9 woodchip carriers from 7 Japanese ports yielded 32 crusteceans and polychaetes
3	Montreal and St. Lawrence River 1980	Plankton samples from 46 ships that had ballasted outside the northwest Atlantic included 132 phytoplankton, 7 protist and 35 invertebrate species
4	North Atlantic	Plankton sampled from a variety of ships and routes included 3 protists, 24 invertebrate and 1 fish species.
	Australia 1981	Identified 4 fish and reported mysids in ballast water of a domestic bulk carrier
5	Coos Bay, OR 1986-91	Plankton samples from 159 woodchip carriers from 25 Japanese ports included 402 species in 24 animal, plant and protest phyla, with the most common being copepods, diatoms, polychaetes, barnacles, mollusks and flatworms
6	Australia 1987-93	Sediment from ballasted cargo holds in 12 Japanese woodchip carriers arriving in Tasmania in 1987-88 yielded 56 phytoplankton species, including abundant diatoms in 4 ships and dinoflagellates cysts in 7 ships. Sediments from 31 out of 83 mainly Japanese woodchip, wheat and ore carriers arriving in Australia in 1987-89 (including the 12 already mentioned) contained dinoflagellate cyst, with toxic species in 4 ships. 343 ships were sampled by 1990, with sampling continuing through at least 1993
7	Great Lakes and upper St. Lawrence River 1990-91	Plankton samples from 86 ships included 110 species of zooplankton in 11 phyla, mainly copepods, cladocerans and rotifers; and 100 species of bacteria, phytoplankton and protists, mainly diatoms and dinoflagellates including 21 bloom-forming, red tide and/or toxic species
	Japan 1991	Ballast water and sediments sampled in ships at 17 Japanese ports by the Japanese Assoc. for the Prevention of Marine Accidents. Results not published
8	Washington State 1991	Samples from 6 Japanese woodchip carriers arriving at Tacoma and Port Angeles in 1991 yielded 21 species of phytoplankton and protists from incubated sediments; and at least 8 orders of organisms in ballast water from 3 ships

Table 2.6 Continued..

	Gulf of Mexico 1991-92	Ballast water samples in 5 of 19 ships yielded Vibrio cholerae, which genetic analysis found to be identical to the strain responsible for the 1991 South American cholera epidemic and found in oysters in Mobile Bay, Alabama
	Germany 1992-95	Plankton sampled in 189 ships, along with organisms in sediment, fouling organisms on tank walls, and larger crabs and fish where possible, included over 350 species, mainly unicellular algae, copepods, other crustaceans and mollusks
9	Chesapeake Bay 1993-94	Plankton net, whole and bottom water samples in 70 ships from foreign ports yielded 275 plant, protist & animal species; and 4 species in sediment from 5 ships
10	Hong Kong 1994-95	Plankton samples from 5 ships from both sides of the North Pacific included 82 species of invertebrates and protists, with copepods being the most common
11	Scotland 1994-95	Plankton sampled from 32 ships and sediment from 24 ships yielded dinoflagellates, diatoms and other organisms. This study is ongoing
12	Baltimore, MD 1995	Plankton samples from 1 coal carrier from Israel yielded 23 species of dinoflagellates and invertebrates, numerically dominated by copepods, bivalves, polychaetes and gastropods
	New Zealand 1995-97	Plankton and bottom water samples from tanks with foreign ballast water in 50 container ships, bulk carriers and break bulk carriers arriving at Lyttelton and Nelson yielded live phytoplankton in 80% of tanks, dominated by diatoms, heterotrophic flagellates and dinoflagellates, and live invertebrates in 83% of tanks with arthropods, molluscs and annelids occurring most frequently
13	Valdez, AK 1996	Plankton from 16 domestic and 1 foreign oil tanker included 68 taxa
	Israel 1996	Cultured ballast water and sediment samples from 17 ships yielded at least 198 heterotrophs (reported as flagellate, pseudopodial and cilate forms), plus diatoms, cnidarians, turbellarians, nematodes, rotifers, gastrotrichs, polychaetes and copepods
	Various sites	Studies are under way or being undertaken in Chesapeake Bay, Long Island Sound, the Port of Morehead City in North Carolina, the Port of Long Beach in California, the Port of Honolulu in Hawaii, the Gulf of St. Lawrence, British Columbia, Sweden and Wales

Source: Cohen, 1998 p.6-7

Table 2.7 Decline of biota with age of ballast water

Carlton et al. 1982	A series of studies conducted on research and commercial ships found the following: Study KB2–No apparent decline in zooplankton density or diversity after 15 and 18 days with little change in ballast water temperature. Study KB3–Zooplankton density dropped 100-fold and diversity dropped from 7 to 1 species in 13 days with a large (19°C) increase in ballast water temperature. Study KB-IS–Zooplankton density remained stable over 7 days of relatively constant temperature, then dropped about 40-fold over 14 days when temperature rose and fell through an estimated 6-8°C. Diversity dropped from 11 to 3 species over the 21 day period. Study TA-I–Net zooplankton density dropped about 60-fold over 64 days, diversity dropped from 12 to 1 species over 95 days. Rotifers were present at the start of the voyage but gone by day 31; microflagellates and ciliates were present through day 64 but gone by day 95. Ballast water temperature varied over 22°C during the 95 days. Study TA-II–Zooplankton density dropped about 20-fold and diversity dropped from 8 to 5 species over 30 days. Ballast water temperature varied over a 14°C range. Study TA-III–Zooplankton density dropped about 20-fold and diversity dropped from 4 to 2 species over 31 days. Ballast water temperature varied over a 15°C range. Study MRI–Zooplankton density dropped 100-fold and diversity dropped from 12 to 2 species over 12 days. A period of elevated temperature and low dissolved oxygen occurred.
Williams et al. 1988	In ships arriving in Australia from Japan, the number of species declined with age of ballast water; the trend suggested few if any species would survive 24 days.
Wonham et al. 1996	On a coal carrier in ballast from Israel to Baltimore, plankton density dropped about 100-fold in 16 days in a ballasted cargo hold (4.5 million gallons). In smaller deck tanks (0.5 million gallons), zooplankton density dropped >10,000-fold in 15 days, phytoplankton dropped 1,000-fold in 4 days. In 16 days the number of species dropped from 38 to 23 in the cargo hold, and from 36 to 3 in the deck tanks, while temperature, salinity and dissolved oxygen remained nearly constant.
Smith et al. 1996	In ships arriving in Chesapeake Bay, there were higher densities of organisms in ballast water less than 14 days old than in water 14-24 days old, but this could be due to differences in water sources. The oldest ballast water containing an organism (one copepod) was 41 days old.
Gollasch et al In press	On a container ship bound from Singapore to Bremerhaven, the density of planktonic diatoms and dinoflagellates dropped >90% in 9 days, and zooplankton density dropped 90% in 4 days. Diatom species dropped from 30 to 4 in 23 days, dinoflagellates from 13 to 0 in 14 days, and zooplankton from 24 to 4 in 23 days. While bound from Colombo to Bremerhaven, zooplankton in one tank dropped from 16 to 4 species in 14 days, but one surviving species increased greatly in abundance.
Chu et al. 1997	In ships arriving in Hong Kong, the number of species declined with the age of ballast water, but about 5-10 species were present in one-year-old ballast water.
Hay et al. 1997	No "free-swimming" phytoplankton were found in ballast water more than one month old.
Ruiz & Hines 1997	In ships arriving in Prince William Sound from the U. S. west coast, the density of annelids and molluscs but not of total organisms was lower in ships with older ballast water. Sampling of 4-6 day old ballast water showed no overall decline in abundance over 48 hours.

Source: Cohen, 1998 p.10

2.4.1 An Administrative View of the Marine Invasive Species

Invasive alien species are widely recognised as one of the greatest threats to biodiversity globally. They also have serious economic, environmental and health impacts, placing major constraints on development. Because of these reasons, states went searching for solutions on a joint platform, to preserve their territorial marine ecosystems and consequently their economies. Shine and Klemm (1999) stated that “In the legal arena, a series of global or regional instruments and programmes have been developed to promote conservation and management of particular species, ecosystems and resources and to address specific categories of environmental threats.”

In the international scale, invasive species were first defined with 1971 Ramsar Convention on Wetlands, which is the first globally applicable environmental convention, referring also to the principles concerning the effects of these organisms on the wetlands, their control and administration. Following Ramsar Convention, invasive species were also referred in “Convention on International Trade in Endangered Species of Wild Fauna and Flora” which entered into force in 1975, “Convention on Migratory Species of Wild Animals (CMS or Bonn Convention)” which entered into force on 1983, “Convention on Biological Diversity (CBD)” which entered into force in 1993, “United Nations Convention on the Law of the Sea (UNCLOS)” which entered into force on 1994 and “Convention on the Law of Non-navigational Uses of International Watercourses” which has not yet entered into force. Table 2.8 indicates the conventions which were prepared with the consideration of invasive species.

Today, “International Convention for the Control and Management of Ships’ Ballast Water and Sediments” which was adopted in 2004, but not yet entered into force, is the most important step towards minimising and ultimately eliminating the transfer of harmful aquatic organisms and pathogens, via vessels.

Table 2.8 Global Conventions and Agreements on Invasive Species

The Convention on Wetlands (Ramsar Convention) Adopted: 1971; In force: 1975	Resolution VII/14 on Invasive species and wetlands
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES or washington Convention) Adopted: 1973; In force: 1975	In Article XIV a provision states that the Convention shall in no way affect the right of Parties to adopt domestic measures restricting or prohibiting trade, taking, possession or transport of species not included in Appendix I, II or III. The provision has been used in Europe to address specific alien species (see section on regional legal instruments.)
Convention on Migratory Species of Wild Animals (CMS or Bonn Convention) Adopted: 1979 ; In force: 1983	The CMS states specifically in article III, 4c. that "Parties that are Range States of a migratory species listed in Appendix I shall endeavour:… to the extent feasible and appropriate, to prevent, reduce or control factors that are endangering or are likely to further endanger the species, including strictly controlling the introduction of, or controlling or eliminating, already introduced exotic species". Article V, 5 states that agreements adding to Annex II should provide for but not be limited to: …. "Conservation and, where required and feasible, restoration of the habitats of importance in maintaining a favourable conservation status, and protection of such habitats from disturbances, including strict control of the introduction of, or control of already introduced, exotic species detrimental to the migratory species;"
United Nations Convention on the Law of the Sea (UNCLOS) Adopted: 1982; In force: 1994	Article 196 (1) of the Convention states that: "States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto."
Convention on Biological Diversity (CBD) Adopted: 1992; In force: 1993	The CBD in article 8h. states that: "Each Contracting Party shall, as far as possible and as appropriate prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species;"
Convention on the Law of Non-navigational Uses of International Watercourses Adopted: 1997	Article 22 affirms that: "Watercourse States shall take all measures necessary to prevent the introduction of species, alien or new, into an international watercourse which may have effects detrimental to the ecosystem of the watercourse resulting in significant harm to other watercourse States".
International Convention for the Control and Management of Ships' Ballast water and Sediments Adopted: 2004	The entire convention deals with the effort to prevent harmful aquatic organisms to be transferred through ballast water and sediments

CHAPTER THREE
IMPLEMENTATIONS OF THE BALLAST WATER CONVENTION

Ballast water, transporting living organisms from one point to another, just like hitch-hikers, appears as an issue of nowadays. The size of the problem can be specified with major financial damages of some countries, as a result of the collapse of some ecosystems until they re-establish equilibrium. Today, the economical, efficacious and applicable management alternatives, brought by the technological developments will help in tackling the ballast water problem.

This chapter reviews the aspect of the legal and administrative arrangements from the stage of the international and national regulations, in relation with the ballast water convention, and provides information on ballast water management methods and technologies of the ballast water treatment systems.

3.1 International Ballast Water Convention

The IMO, instead of preparing amendments to the, previous conventions issued a new convention about ballast water, clearly indicated the importance of the global threat posed by the living organisms carried with ballast water and the approach of IMO to these threats.

The purpose of the proposed Convention is specified by IMO as follows: "to prevent, minimize and ultimately eliminate the risk of introduction of Harmful Aquatic Organisms and Pathogens which use the ballast water as a hub."

Since the Convention has not yet entered into force, it does not impose any liabilities to the Party states. However, it will bring serious liabilities to the Party states, following entry into force after 12 months, when 30 states, representing 35% of the world merchant shipping tonnage have ratified it. It is estimated that the ships of nonparticipant states may face difficulties while they are in the ports of the Party states. General information on the Convention signed by 16 states as of October 21, 2008 is summarized in Table 3.1.

Table 3.1 Summerized information of the Convention

Convention	International Convention for the Control and Management of Ship's Ballast Water and Sediments
Adopted by	International Maritime Organization (IMO)
Adopted on	13 February 2004
Enter into force	12 month after ratification by 30 States, representing 35% of the world merchant shipping tonnage
Status of ratification	In October 22, 2008 is 16 States, representing approximately 14.24 % of the gross tonnage of the world's merchant shipping. (Gibson, 2008)
Ratified States	Spain (has become the first state to sign, also Brazil has. But Brazil has not yet submitted an instrument of ratification), Barbados, Egypt, France, Kenya, Kiribati, Liberia, Maldives, Mexico, Nigeria, Norway, Saint Kitts & Nevis, Sierra Leone, South Africa, Syria Arab Republic, Tuvalu (Gibson, 2008 & IMO, 2005a)
Apply to	All ships (new & existing vessels) on international trade
Not Apply to	National/local trade only Navy/governmental, non-commercial ships Permanent ballast water in sealed tanks
Requirements	A valid Certificate, a Ballast Water Management Plan and a Ballast Water Record Book
Also includes	Exchange of ballast water; treatment by mechanical, physical, chemical or biological processes, either singularly or in combination
Guidelines to the Convention	G 1 Guideline for Sediment Reception Facilities G 2 Guideline for Ballast Water Sampling G 3 Guideline for Ballast Water Management Equivalent Compliance G 4 Guidelines for Ballast Water Management and Development of Ballast Water Management Plans G 5 Guideline for Ballast Water Reception Facilities G 6 Guidelines for Ballast Water Exchange G 7 Guidelines on Risk Assessment under Regulation A-4 G 8 Guidelines for Approval of Ballast Water Management Systems G 9 Procedure for Approval of Ballast Water Management Systems that make use of Active Substances G 10 Guideline for Approval and Oversight of Prototype Ballast Water Treatment Technology Programs G 11 Guideline for Ballast Water Exchange Design and Construction Standard G 12 Guidelines for Sediment Control on Ships G 13 Guideline for Additional Measures including Emergency Situations G 14 Guideline on Designation of Areas for Ballast Water Exchange G 15 Guidelines for Port State Control

The Convention includes mandatory articles, as well as guidelines for the states to help them establish their own management strategies. Preparation of the regional and national models specific for every state shall end up as an overall multi-state ballast water management system. The Code of Best Practices for Ballast Water Management, issued by the Shipping Federation of Canada (2000) refers to the need of an integrated approach in the article 10 “to strive toward global, integrated ballast water management strategies in conformity with internationally agreed principles that respect national and regional aquatic ecosystem.”

The marine environment will be protected while in use, consequently establishing management strategies in regional, national and international scales.

3.1.1 The Important Regulations of the Convention

The articles of the Convention, listed below are an indication of serious liabilities which will be imposed on the Party states, in violation of the Convention.

- Parties undertake to encourage the continued development of Ballast Water Management and standards to prevent, minimize and ultimately eliminate the transfer of Harmful Aquatic Organisms and Pathogens through the control and management of ships’ Ballast Water and Sediments.

- Each Party shall, with due regard to its particular conditions and capabilities, develop national policies, strategies or programmes for Ballast Water Management in its ports and waters under its jurisdiction that accord with, and promote the attainment of the objectives of this Convention.

- Each Party undertakes to ensure that, in ports and terminals designated by that Party where cleaning or repair of ballast tanks occurs, adequate facilities are provided for the reception of Sediments, taking into account the Guidelines developed by the Organization. Such reception facilities shall operate without causing undue delay to ships and shall provide for the safe disposal of such Sediments that does not impair or damage their environment, human health, property or resources or those of other States.

- Parties shall endeavour, individually or jointly, to:

(a) promote and facilitate scientific and technical research on Ballast Water Management; and

(b) monitor the effects of Ballast Water Management in waters under their jurisdiction. (IMO, 2004)

Such research and monitoring should include observation, measurement, sampling, evaluation and analysis of the effectiveness and adverse impacts of any technology or methodology as well as any adverse impacts caused by such organisms and pathogens that have been identified to have been transferred through ships' Ballast Water.

3.1.2 Requirements of the Convention

1. Valid Certificate: All vessels of the Party states are required to have a certificate, indicating that they are undersigned party of the International Ballast Water Convention, and are required to apply all the terms in due diligence.

2. Ballast Water Management Plan: The plan to be carried on board. The plan gives;

   - information to the master regarding the requirements to ballast water reporting to different port authorities,
   - assistance to the master in exchanging the ballast water in a safe manner
   - safety procedures for ship and crew,

- ❖ description of the actions to be taken to implement the ballast water management requirements,
- ❖ procedures for disposal of sediments,
- ❖ step-by-step plan when using exchange,
- ❖ a list of circumstances in which ballast water exchange should not be undertaken (critical situations of an exceptional natural conditions, force majeure due to stress of weather, or any other circumstances in which human life or safety of the ship is threatened).

3. Ballast Water Record Book: It is mandatory to keep regularly onboard this record book which will indicate the place, time and the amount of ballast water operations of the vessel

3.1.3 Methods Recommended in the Convention

The Convention suggests two different methods, in order to minimise the problems caused by the transfer of ballast waters: the exchange method and treatment alternatives.

Some states have already implemented various measures voluntarily, to protect their territorial waters (territorial waters and Exclusive Economic Zones-EEZ), before the Convention has entered into force. Canada, Australia and the United States of America are the first states who implemented Ballast Water Exchange method voluntarily. Table 3.2 indicates the criteria on Ballast Water Exchange method of the states that voluntarily implement the Convention.

Another method emphasised by the Convention is on-board ballast water treatment systems, researches are held by some of the states about onboard ballast water treatment systems. The developed treatment systems are tested in laboratory media and on-board trials, to determine its applicability. Thus, approved treatment systems that provide IMO criteria are developed and various treatment alternatives are presented to be installed on vessels.

One of the most important points of the Convention is the acceptable amount of living organisms that may be contained in the treated or exchanged ballast water, prior to discharge. IMO specified the acceptable discharge standards after the employment of exchange method, as well as treatment systems, under D-1 and D-2 headings (Figure 3.1).

D-1 Exchange Standard:

- efficiency of at least 95 % volumetric exchange (sequential method) or
- pumping-through three times the volume of a tank (flow-through method, dilution method)

D-2 Performance Standard:

- less than 10 viable organisms per cubic meter greater than 50µm and
- less than 10 viable organisms per mililiter smaller than 50µm and greater than 10µm and
- limited number of indicator microbes (bacteria)

Figure 3.1 summarises D1 and D2 standards which will gradually become mandatory, in accordance with the construction date of vessel and the gross tonnage. Accordingly, the vessels of the Party states will have to retrofit/fit their onboard treatment systems which will provide the D2 standards, until 2016. D1 standard, i.e. the exchange method is acceptable during the transition period.

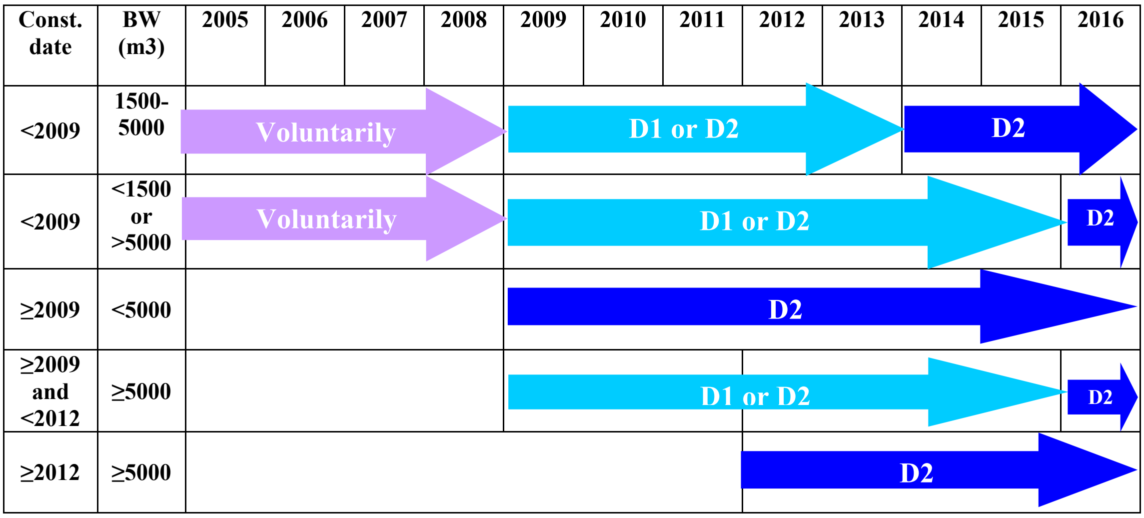


Figure 3.1 The application date for new and existing vessels is dependent on the construction date and the capacity of ballast water.
(Source: GL, 2006)

3.2 Ballast Water Management in Turkiye

Recently, Turkish Maritime Zones have been among the places that were mostly affected by the harmful aquatic organisms, carried by ballast waters. As an example, Mnemiopsis Leidyi penetrated into the Black Sea in 1989, via the ballast waters of vessels. They depleted planktons, the food of anchovy, which resulted in a severe drop in the anchovy population in the Black Sea.

Olgun (2007) mentioned the reasons of these negative impacts on the Turkish Maritime Zone under three headings:

- Opening of the Suez Canal in 1869, development of the oil zones in the Middle East and the rise of the South Eastern Asian economy,
- Shipment of the Caspian oil to the Western markets via sea,
- Particularly, the origination of the oil transport from the Black Sea to the other seas, arrival of these vessels to conduct this transportation to the Black Sea without cargo, instead carrying ballast waters.

3.2.1 Overview of the Turkish National Legislation

Article 4 of the Law on Ports, No. 618, issued in the Official Gazette dated 01.09.1922 refers to the ballast water as, ”...filth, debris, ballast, wastes and the like are not allowed be discharged to the places, prohibited by the Harbour Master”.

The item c of Article 2-2 of the addendum of the Governmental Decree on the Turkish Exclusive Economic Zone, dated 5.12.1986, No. 86-11264, states that “It has the exclusive rights and the authority to bring forth the necessary arrangements and the controls, in order to protect and preserve the marine environment, and to prevent, reduce and control marine pollution”.

The sections on ballast waters, in the Environmental Impact Assessment of the Coastal Constructions, Sector Guide of the Republic of Turkiye, Ministry of Environment and Forestry are stated below:

Aside from coastal construction, an important issue to consider environmentally and to seek alternative remedies is ship-borne wastes and the treatment/elimination and management of ballast waters... The development of maritime sector and the coastal constructions will bring a growth in the marine traffic, increasing the possibility of disposal and/or discharge of bilge/sludge, ballast, toxic paints and wastes to the environment in larger amounts... The environmental impacts on the aquatic ecosystem arise from the uncontrolled discharge of the ballast and waste water, leakages, accidents, chemicals and heavy metals which might have mixed with the water through wastes produced during construction, repair and painting of ships... Discharge of ballast, residual water and similar liquid wastes to the port by arriving and departing vessels should be prohibited. If such liquid water is to be discharged in the port, the necessary units must be established. (Republic of Turkiye, Ministry of Environment and Forestry, 2006)

In all of the port regulations and directives in overall ports of Turkiye, it is stated that “filth, debris, ballast, waste and the like are not allowed be discharged; lubricants and pollutants are not allowed to be pumped into the sea; and tanks and bilges are not allowed to be washed within the port boundaries.”

Also Council Directive concerning Port State Control, dated June 19 1995, No. 95/21/ec, and Port State Control Regulation, issued in the Official Gazette dated March 26, 2006, No. 26120 include articles related to the ballast tanks and the review of the associated forms on ballasting.

3.2.2 Actions on the Ballast Water Management in Turkiye

As the International Ballast Waters Convention was brought up to the agenda in 2004, the Undersecretariat for Maritime Affairs which is the responsible authority for the maritime has awarded the contract for the “Control and Management of Harmful Aquatic Organisms Carried with Ballast Water" to TÜBİTAK (the Scientific and Technological Research Council of Turkiye) as of July 21, 2006. The project, aimed to be completed in two years was delivered as of 01.08.2008.

The project aimed at defining the legal liabilities and the necessary actions to be taken, after Turkiye becomes a party to the “International Convention for the Control and Management of Ships’ Ballast Waters and Sediments” and determining the necessary managerial/technical understructure and minimising the damage of the harmful aquatic organisms. Accordingly, the work completed in the Turkish Maritime Zone and in areas included in the associated marine ecosystems, on eliminating or minimising the adverse effects of aquatic organisms and pathogens, carried with ballast waters, are listed below:

1. Preparation of an inventory of the marine traffic, amount of ballast water and harmful aquatic organisms and pathogens carried;

2. Identification of the future trends;
3. Risk assessment, based on the aquatic organisms and pathogens, carried by ballast water;
4. Generation of Geographic Information System (GIS) maps;
5. Creation of a database;
6. Review of the relevant international legislation and practices, and determination of actions, concerning the national practices;
7. Preperation of the national legislation;
8. Defining the administrative structure to be established;
9. Identifying the existing technical infrastructure; and
10. Establishing a training system.

3.2.3 Problems Encountered in Turkiye Concerning Ballast Water

Prior to the execution of the International Ballast Water Convention, Republic of Turkiye, the Office of the Prime Minister, Undersecretariat for Maritime Affairs has taken series of actions to gather data and to compare the obtained data for accuracy. The issues were determined, particularly pertaining to the work conducted with the co-operation of Port State Control Officers and personal interviews:

- Ballast in the tanks cannot be completely pumped out, due to the reasons such as inclination of the ship during deballasting and that the pump cannot be capable to have efficient suction of the ballast in the tank completely.
- Ballast cannot be pumped out on-time, due the reasons, such as the incompatibility between the capacity of the ballast pumps and ballast lines in some of the old ships, and the inadequacy of generators due to overload, when used together with other equipments which should be used simultaneously with the cargo and the ballast pumps.
- Problems arising from the port authorities, when they do not allow the risky ballast to be pumped out.

- ❖ Due to polluted seawater in some ports, the ship has to take in this dirty ballast, in order to be capable of making a safe voyage. This also causes burdens at the destination port.
- ❖ Especially in places where there is an input of fresh water, ballast comes together with sediments. Another case that is undesirable for the ship is the penetration of sediments into the tanks. It accumulates in tank posts and brackets, making it more difficult to be discarded from the tank, and clogs the pump, as well as allowing for the inflow of benthic organisms into the tank. In addition, sludge / ooze accumulation is regarded as constant in the ships, causing economical losses. (Figure 3.2)

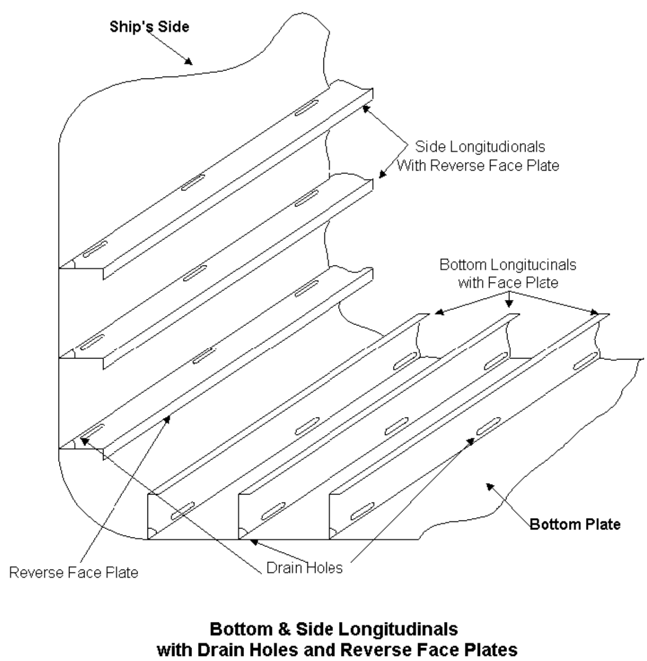


Figure 3.2 Extra drain holes and scallop holes in longitudinals and location of faceplate stiffeners. (Source: Taylor & Rigby, 2001, p. 39)

- ❖ Since the number of crew is limited, simultaneous tracking of both cargo and ballast operations causes some defects. This often causes overflow of the ballast from the tanks.

- The ballast measurements of the ships during the voyage do not yield healthy results. The ship is exposed to external forces during the voyage. Movements such as heeling, pitching, rolling prevent the ship to move in a straight trim line. And this causes errors in the ballast water measurements in the tanks.
- In old types of vessels (particularly in bulk carriers), the complex structure of the ballast systems requires a high number of crew for the operation. Errors occur, due to the limited number of crew onboard and the practice of the operation by many persons.
- Vessels are required to make several declarations, prior to their arrival at the port. These declarations are made via agencies, acting as the land representatives of the ships. In accordance with the Ballast Inventory Study which is the first aim of the project awarded to TÜBİTAK by contract, a website is prepared to serve for ballast reporting (lodos.mam.gov.tr/lodos). This aimed at facilitating the ballast water declarations of the ships. However, the Port State Controls determined that the ship agencies mostly provided incomplete or incorrect information, due to their lack of knowledge and correct information on the International Ballast Waters Convention. In addition, it is also determined that the ship officers and seamen have made wrong or incomplete declarations, due to insufficient language the convention declares and/or Ballast Waters Convention knowledge. The above mentioned is the most important factor that makes the system inefficient, arising from not giving the necessary importance to this implementation.
- All vessels, in particular, container ships, ferries, ro-ro/passenger liners keep ballast constantly in fore peak tanks and in some double bottom tanks, in order to sustain the stability and to move in a proper trim. This ballast water which has no circulation and aged in time, is not included in the operations and even not recorded in ballast reportings at all.

3.3 Ballast Water Management Alternatives on the Convention

Ballast water management begins prior to intake of ballast water onboard and continues until the last step where the ballast is totally discharged. During this period, the vessel is responsible of implementing the most appropriate management plan, allowed by the weather, sea and port conditions. The port states also contribute to this managerial process. Some of the set criteria are: conduct of ballast exchange by the vessel outside of EEZ, berthing after deballasting, declaration of the place of ballast water intake, etc. The case of the Australian Quarantine and Inspection Service (AQIS, 2008) can be cited as an example. AQIS classifies the ballast as high-risk or low-risk ballast in accordance with the place of intake, and decides whether the discharge of ballast water is to be permitted in Australian territorial waters.

After the adoption of International Ballast Water Convention, many scientific and technological researches were held and proposed management alternatives. The main headings of these alternatives are ballast water exchange, on-board treatment and on-shore treatment. The diagram below provides information on the contents of Ballast Water Management options.

Ballast Water Management Options

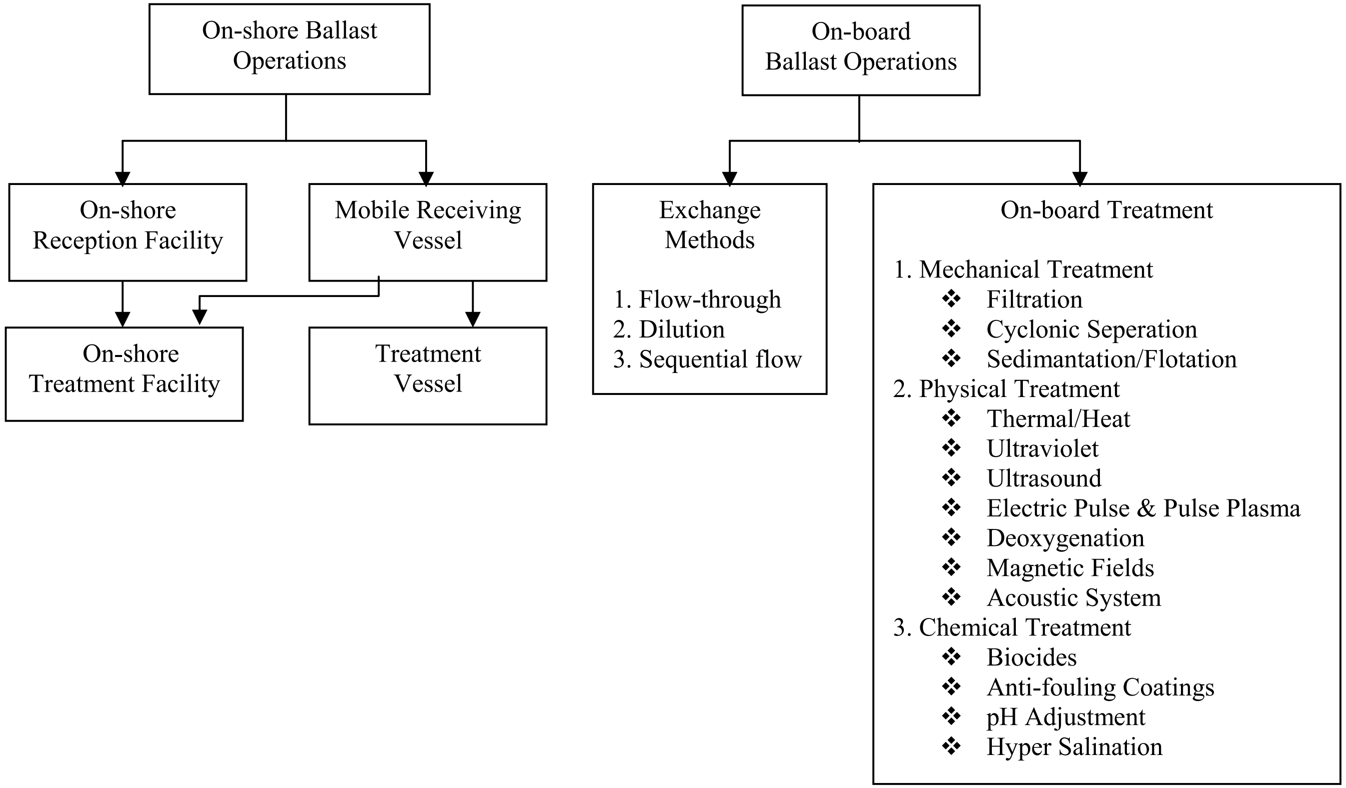


Figure 3.3 Ballast water management options

3.3.1 Ballast Water Micro-management

The first step of the ballast management is to take in as clean as possible ballast. Cohen and Foster (2000) named this micro-scaled managerial practice as micro-management, and listed the selection options to be considered for this practice as follows:

Not Ballasting;

- in areas that are known to contain harmful organisms or phytoplankton blooms,
- in areas with local outbreaks of infectious water-borne diseases,
- in waters with high sediment loads,
- where propellers may stir up the sediment,
- near dredging operations,
- in shallow water,
- near sewage discharges,
- in areas with poor tidal flushing,
- not ballasting at seasons when harmful plankton are abundant,

Also;

- at night when many types of organisms- benthic, epibenthic and planktonic organisms- migrate closer to the surface,
- ballasting through intakes located high on the ship's hull when in shallow water, to avoid entraining bottom sediments or organisms living near the bottom,
- loading fresh water as ballast when expecting to deballast in salt water; and salt water as ballast when expecting to deballast in fresh water.

Not disposing/ deballasting;

- of ballast tank sediments,
- near aquaculture areas, seafood harvesting areas, marine sanctuaries or parks, coral reefs or other sensitive sites.

Ballast intake with the consideration of micro-management criteria will improve the efficiency of the use of the exchange method, as well as on-board treatment system.

3.3.2 Ballast Water Exchange

The main method suggested by IMO in the Convention is the exchange method. Careful and attentive practice of this method is necessary, in order to maintain it as an alternative until 2016.

In the second chapter, it is stated that the reason why the diversity of the species in the coastline is more than in the oceans. It is also discussed that the seawater composition in the coastline can change due to fresh water input (rivers). When marine species are transferred to a different ecosystem other than their own, they will not be able to survive due to lack of a suitable environment, or will only be able to survive after converting into a different form (resting stage). For example, a species living in seawater with high salinity rate would face difficulties in surviving in fresh water/brackish water environments. Species which can adapt to different environmental conditions, due to high threshold values, are exceptions. The ballast exchange operation is developed exactly on this base concept. In other words, the species taken in from coastal environment thru ballast water and exchanged via exchanged method during the voyage, are no longer coastal species, therefore exchanged species due to the different ecosystem shall not be able to survive at the environment of the destination port.

Although the exchange method is an advisable option to minimise the amount of living organisms in the ballast water, the owners/operators and the masters of the vessels avoid the implementation of this method for its risks.

Negative weather/sea conditions cause the stability of the vessel and pressurizing ballast tanks damage the ship during the exchange operation, therefore is not preferred by the masters (personal interview with the masters). Ro-ro cargo vessel “Cougar Ace,” presented by Rygh (2007) sets an example to this. She, loaded with approximately 4,700 cars, listed approximately 60 degrees outside Alaska during ballast transfer operations.

Owners/operators of the vessels do not prefer the exchange method, due to the extra costs they incur (such as costs arising from overworking of the pumps, extending the distance by changing vessel route to apply the exchange method).

Restricting factors of the ballast water exchange operation are summarised below, in the light of the approaches of Mackey, Tagg and Parsons (2000), Meyrick and Associates (2003), Pederson (2000), and Buck (2005):

- the value of GM or KG would fall below minimums at any point during the operation, or that open water shear stress or bending movents would be exceeded, or that hog or sag would be excessive, or that excessive trim would be experienced, or that the propeller would be exposed enough to cause racing. Free surface effect must be allowed,
- the use of machinery requiring fuel and maintenance on pumps etc., and additional deck maintenance as a result of ballast water floating on deck,
- the deviation at sea necessary to access areas suitable for exchange (requiring fuel and, possibly, faster steaming),
- the delay – demurrage, dispatch/half dispatch costs under the charter parties,
- possible delays caused by long ballast exchange procedures,
- some reduction in cargo loading flexibility and total cargo capacity since some ships can be “pre-ballasted” prior to entry into port in order to minimize intake of port water,
- it is unable to exchange outside the Exclusive Economic Zone for the vessel (coastal trade limitation or safety consideration),
- in areas of visible plankton or algal bloom restrict,
- the resource costs – additional crew over the longer term with additional peak work load,

- potential cost associated with piping and pumping modifications required to minimize discharge for heel and trim control in port. (i.e. some ships may not have the ability to transfer ballast between port and starboard wing tanks),
- operating costs associated with possible crew overtime for ballast exchange pumping operations.

A series of procedures needs to be followed, in order to minimise the adverse impacts of a ballast exchange operation on the vessel. The procedures, included in the guidelines, issued by IMO in 2005 which should primarily be considered are listed below:

- avoidance of over and under-pressurization of ballast tanks,
- avoidance of free surface effects on stability and sloshing loads in tanks,
- exchange in acceptable weather conditions (avoided in freezing weather conditions),
- avoidance of the weather routing in areas seasonably affected by cyclones, typhoons, hurricanes, or heavy icing conditions,
- minimum/maximum forward and aft draughts,
- contingency procedures for situations which may affect the ballast water exchange at sea, including deteriorating weather conditions, pump failure, loss of power, etc.,
- monitoring and controlling the amount of ballast water.

With its limitations, drawbacks and risks, ballast water exchange has been an instrument, prior to entry into effect of the Convention. The practice of this operation is inevitable; however some states require ballast water exchange from the vessels that enter the ports. Table 4.2 presents information on ballast water exchange practices of some states.

Table 3.2 Distance and depth requirements for ballast water exchange

Implementing Body: Laws, Regulation or other Authority	*Requirement for Exchange*
IMO: Guidelines (1991)	In water at least 2,000 meters deep.
US: NANPCA (1990) and NISA (1996)	Outside the US 200-nautical-mile EEZ.
US: Regulations Implementing NANPCA (1993)	Outside the US and Canadian 200-mile EEZ and in water at least 2,000 meters deep.
US: Proposed amended regulations for NANPCA and NISA	Outside the US and Canadian 200-mile EEZ and in water at least 500 meters deep.
US: Final Rule re-exporting Trans-Alaska Pipeline oil (1996)	In water at least 2,000 meters deep.
US: US Navy procedures (1994)	At least 12 miles from shore.
Canada: Voluntary Guidelines (1989)	In water at least 2,000 meters deep; backup zone specified in water over 340 meters depth.
Israel: Notice to Mariners (1994)	Beyond the continental shelf or freshwater current effect.
Chile: Regulations (1995)	At least 12 miles from shore.

Source: (Cohen, 1998 p.22)

Ballast exchange alternative is regarded as an applicable alternative for oceangoing vessels, with respect to limitation of distance. However, it may cause problems for vessels engaged in inland marine transport (Baltic, Black Sea, Marmara Sea, Aegean Sea, and Mediterranean Sea). The distance between the northernmost and the southernmost of the Mediterranean Sea and the Black Sea, which is less than 400 nautical miles, is a point to be considered in the national and international management plans of the states located in this region.

Three different types of exchange methods are stated in the Convention: Sequential Method, Dilution method, and Flow-through method.

3.3.2.1 Sequential method (Empty-Refill)

IMO defined Sequential method (2005b) as "a process by which a ballast tank intended for the carriage of ballast water is first emptied and then refilled with replacement ballast water to achieve at least a 95 per cent volumetric exchange."

The sequential method which is referred to in the sources as the most accessible and cost-effective tool, seems to be preferable since no additional equipment is needed and it is an easily applicable process. However, it has several drawbacks. Table 3.3

summarises the drawbacks which may be caused by the sequential method, by different references.

Table 3.3 Drawbacks of sequential method

Drawbacks	***References***
❖Emptying of certain tanks may lead to significantly reduced stability, higher stresses, high sloshing pressures, and/or reduced forward drafts ❖Reduced forward draft would be an increased probability of bow slamming	ABS, 1999
❖It may deviate the vessels intended voyage, or delay the voyage	DNV, 2005
❖It is difficult to completely remove sediments and residual water from the bottom of ballast tanks ❖Organisms stuck to the sides of the tank or structural supports within the tank will not be readily removed ❖During stormy or rough seas it is unsafe for a ship to exchange ballast water. Thus, organisms remaining inside the ballast tanks may be discharged at a later time into ports and harbors if the exchange fails to remove all organisms	MITSG, 2006
❖Reduce propeller and rudder immersion ❖Reduce draft ❖Bottom slamming	DNV, 2007
❖Need for extra crew ❖Dangerous impact of stress on the hull during the operation, especially over-aged and long vessels (in length) ❖Damage in vessel structure and ballast tanks due to free surface effect (corrosion on vessel's plating due to wearing of ballast tank coating or paint)	

An empty-and-refill exchange could potentially make a ship unstable or prone to slamming (by discharging too much ballast for the sea conditions), cause insufficient propeller immersion, or impose unacceptable stresses on the hull (by changing the buoyancy in one section of the vessel relative to another). Stability problems are in general likelier for small ships, and unacceptable stresses are likelier for large ships…Empty-and-refill exchange is unsafe for vessels over 40,000 deadweight tons. (Cohen, 1998)

Cohen (1998) covered the impact of empty-refill method on the vessel stability in his studies (Table 4.4).

Table 3.4 Safety assessment of open-ocean, empty-refill ballast exchange.

	Length × Breadth (meter)	*Displacement Tonnage (metric tons)*	*Deadweight Tonnage (metric tons)*	*Ballast Capacity (cubic meters)*	*Study Results*
Bulk Carrier	181.36 × 22.86	37,700		15,936.58	Modelling found no stability problems. Bending moments and shear forces safe in seas with 3 meter significant wave heights. May occasionally exceed design values in seas with 6 meter significant wave heights
Container ship	206.35 × 28.96	40,000		5,299.58	
Tanker	269.44 × 32.31	110,000		37,551.29	
Bulk Carrier	283.46 × 47.24		141,500	56,289.07	Modelling found instances of propeller emergence, unsafe bending moment and shear force.
Bulk Carrier	259.99 × 42.98		150,000	67,456.04	Modelling found no problems with stability or hull girder loads.
Bulk Carrier	225.55 × 32.00	79,000	70,000		Modelling found all stability criteria met; found instances of propeller emergence, increased risk of forward slamming,unsafe bending moment or shear forces.
Bulk Carrier	289.56 × 42.67	189,000	165,000		
Bulk Carrier			188,200		Displacements gauges showed stress variations judged to be undesirable.

Source: (Cohen, 1998 p. 23)

One modelling study based on three ships of 37,700 to 110,000 tons displacement found that empty-and-refill exchange conducted at sea would produce no instability problems and place no unacceptable stresses on these ships until the seas reached significant wave heights of somewhere between 10 and 20 feet. One modelling study on a bulk carrier of 150,000 deadweight tons uncovered no problems with stability, bending moment or shear forces if exchange is conducted in an appropriate sequence, while two modelling studies and records of displacement during an exchange indicated unsafe stresses for four bulk carriers of 70,000 to 188,000 deadweight tons. (Cohen, 1998)

Emptying ballast tanks introduces dynamic loads from waves and ship motion which may exceed safe hull shear and bending moments, as well as affect draft, trim, stability and propeller depth. Figure 3.4 shows how waves affect the stress loading on ships. (Oemcke, 1999)

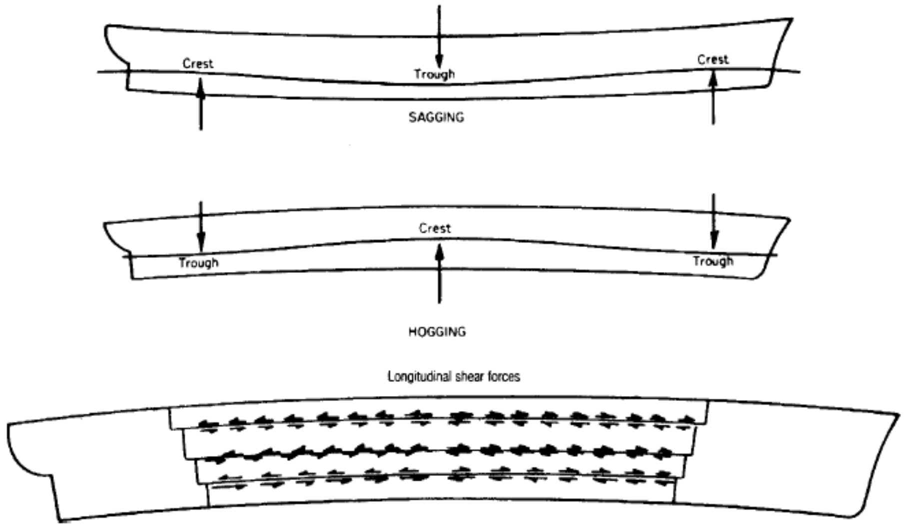


Figure 3.4 Effect of wave motion on bending and stress in ship's superstructure (Oemcke, 1999)

3.3.2.2 Dilution method

Dilution method is identified by IMO (2005b) "a process by which replacement ballast water is filled through the top of the ballast tank intended for the carriage of ballast water with simultaneous discharge from the bottom at the same flow rate and maintaining a constant level in the tank throughout the ballast exchange operation."

Ballast dilution is much safer than reballasting as there are no static load changes since tanks are continuously full throughout the process. There is a risk of pressurisation or depressurisation of ballast tanks, which might occur if the water inlets and outlets are poorly matched in size, which could damage the structure of the ship. Another concern with continuous dilution of ballast tanks is erosion of steelwork, scouring of protective coatings by coarse particles and a significantly reduced life of pumps and bearings. (Oemcke, 1999)

3.3.2.3 Flow-through method

Flow-through method is identified by IMO (2005b) as "a process by which replacement ballast water is pumped into a ballast tank intended for the carriage of ballast water, allowing water to flow through overflow or other arrangements."

The flow-through method involves pumping open-ocean water into a full ballast tank. Ballast equal to approximately three times the tank capacity must be pumped through the tank to achieve 95% effectiveness in eliminating aquatic organisms. (ABS, 1999)

Table 3.5 Drawbacks of flow-through method

Drawbacks	***References***
❖Air pipes are not designed for continuous ballast water overflow ❖Certain watertight and weathertight closures (e.g. manholes) which may be opened during ballast exchange, should be re-secured ❖The overflow of ballast on deck is prone to icing in cold environments	IMO, 2005
❖The risk of over-pressurization of the ballast tanks Risks caused by opening manholes to provide effective exchange and to prevent over-pressure in tank ❖Risk of marine pollution from possible oil leakages from deck machinery (cranes, etc.) ❖Exposure of the welded points in the tanks ❖The airflow pipes of ballast tank are not designed/installed to resist continuous overflow ❖Risk of seawater contamination to the cargo, due to water leakage from the damaged/stressed ballast tanks ❖Decreases service period ballast lines, pumps, valves etc. ❖Increased maintenance costs of pumps and tanks ❖Loading on the diesel generator and additional fuel consumption ❖Increased volume of wastes (sludge, bilge, exhaust, etc.)	

3.3.3 Ship-board / On-board Treatment Alternatives

On-board treatment is regarded as a concept to help in protecting all seas from ballast water-originated non-native species and their negative effects, where each ship treats its own ballast water.

According to the International Ballast Water Convention, all ships by 2016 must be equipped with one of the on-board treatment systems. Construction date of the ship is on or after 2009 are not expected to face major problems, since these systems will be included in the design stage. However, the same is not valid for the vessels in service – construction date of the ship before 2009. The existing vessels will have to select and be equipped with an on-board treatment system that requires minimum modification, and is more economical until 2014 or 2016, according to their tonnages. Existing ships will have to apply one of the Ballast Water Exchange methods that is suitable to their respective design, in the transition period until the on-board treatment system is installed.

Prior to the adoption of the Ballast Water Convention in 2004, an in-depth research on the on-board treatment systems was initiated. Various systems were developed under mechanical, physical and chemical treatment categories that address to various vessel types, sizes and ballast capacities. Nowadays, compact treatment systems are developed which use the state-of-the-art technology, having relatively lower costs, with minimum human factor, owing to the experiments conducted both in laboratories and on-board. Some treatment systems which meet the requirements of D-2 standard have received approval from IMO and were included in the systems which can be installed on vessels (Annex IV).

Each of the ballast treatment alternatives eliminates different living organisms with different methods. While the living organisms that are affected by each system are different, the systems have many advantages and some drawbacks within themselves. The treatment systems should be designed in more detail and durability required, also considering the capacities of ballast pumps of the ships, type of cargo loaded, loading/unloading conditions of cargo and the changes in the flow rate of the ballast water taken-in or discharged. In short, no system is perfect stand-alone. The system to eliminate the maximum extent of the organisms, require higher doses of chemicals or higher consumptions of energy etc., to increase the effectiveness to a greater extent, which brings forth greater drawbacks and risks, too.

Research conducted by treatment companies, in cooperation with researchers and scientists bring forth that some systems are capable stand-alone (solo treatment) where others yield more effective results with the combination of multiple systems (combined treatment). Glosten-Herbert, Hyde Marine (2002) explains the reason for the efficiency of the combined systems as follows:

While some have been shown to be quite effective against certain types of aquatic life, a single technique has not yet been found that can handle all of the target organisms with reasonable dosages or equipment parameters. The biodiversity is just too great (in terms of size and sensitivities). Differences in the size of ships and the quantities of ballast water handled, add to the complexity of the ideal solution. Finally, a ship's trade route may alter the primary target organisms when a risk-based approach to control of species is introduced or regional standards are encountered. For these reasons, most investigators currently believe that a two- or three-stage treatment system offers the most flexibility and potential for addressing a wide range of organisms. (Glosten-Herbert, Hyde Marine, 2002)

The first stage of combined treatment systems aims at removing as much as possible larger organisms and/or suspended solids from ballast water. The aim of the secondary treatment is to neutralize the remaining organisms, disinfect the ballast water, and render it suitable for discharge. For instance, when the filtration method is used as a solo treatment, the mesh size range should be reduced as much as possible, for the maximum amount of species elimination. However, this causes rapid clogging of the filters, it also restrains the ballast water to be taken in with high flow rate. Additionally, stand-alone use of the filtration method is not efficient, due to the inverse proportion of the mesh size range with the cost. On the other hand, use of ultraviolet method as a solo treatment reduces the efficiency of the method, due to turbidity arising from the suspended matters in the ballast water. It is also found out with research that it is not a successful method in destroying larger living organisms. Although both systems are not capable of providing the required efficiency when applied independently, the efficiency increases significantly, when they are combined together. At first stage, use of filtration method provides for the purification of the ballast water from larger living organisms and suspended matters. To have an optimum mesh size during this procedure, it facilitates the intake of ballast water in the desired flow rate. Consequently, the living organisms that could not be eliminated in the first-stage-treatment can be eliminated efficiently with the use of the ultraviolet system.

On-board treatment systems – as referred to in the following section– are complex systems that mostly require modification in certain parts of the ship (engine room, pump room etc.), in order to be adaptable to the ship. The points to be considered in the selection of an on-board treatment system, particularly for the existing ships are stated below by GL (2006):

- reserve space (e.g. in the engine room) to arrange the treatment system,
- possible additional pressure of the ballast pumps to cover the pressure losses of the ballast water treatment plant,
- the capability of the ballast system to enable a monitored and flow controlled by-passing of the treatment plant i.c.o. plant failure,
- additional power supply as demanded from the treatment systems.

Buck (2005) evaluated on-board treatment systems with another point-of-view. Buck claims that on-board treatment systems present an alternative for ships that temporarily operate without ballast, i.e. that are "no-ballast-on-board" (NOBOB). This way, the organisms within the residual ballast water and in the sediments retained in the ship will be completely destroyed. In short, the ballast waters and sediments already less in amount will be highly purified from living organisms.

The cost analysis referred to by Taylor and Rigby (2001), in the article of Waite et.al. (2003), discusses that on-board treatment is at least ten times more expensive than ballast exchange method. This management alternative, actually being not economical at all, is the most important requirement of the Convention. Therefore, installing these systems on vessels will bring many liabilities, primarily upon owners and operators, classification societies, ships' flag states, port states and the crew.

The following section, briefly outlining on-board treatment systems, provides information on operating principles, advantages provided and the drawbacks to be considered related to these on-board treatment systems.

3.3.3.1 Mechanical treatment

Filtration, cyclonic seperation and sedimentation/flotation are among the alternatives of mechanical treatment.

Filtration:

Inactivation Process: Ballast water can be filtered before it enters the tanks or while it is being discharged. The advantage to filtering as water is pumped into the tanks is that organisms that are filtered out may be retained in their native habitat. If ballast water is filtered while being discharged, proper disposal of organisms is required to eliminate accidental introductions. A back washing mechanism cleans the filters and collects organisms to prevent their accidental release.

Systems designs are determined by the size and type of particles to be removed. The complexity and cost of filters increase as the quantity of material removed from ballast water increases (smaller particles). Filtered organisms could be concentrated and stored on board ship and disposed of at a shore-based facility or discharged back into the water if regulations permit.

Self-cleaning strainer have been developed with automatic control systems incorporating cleaning cycles that can be activated by differential pressure or on a time cycle. Flow-through centrifugation systems can separate particles prior to filtering to reduce filter clogging. Wedge-wire filtration systems have high flow rates and are cleaned by scraping, rather than backwashing, which eliminates the need for storing and treating backwash water and thereby reduces the overall size of the filtration unit.

Table 3.6 Excluded organisms according to the different mesh sizes

Mesh Size	Excluded Organisms	References
No filtration (sea chest- screened to 15 mm	❖Excludes large marcophytes, fish and invertebrates	Buchholz et.al.,1998
	❖Prevent the intake of large objects	CETS, 1996
250 µm filtration	❖Excludes all fish, most invertebrates and all macrophytes.	Buchholz et.al.,1998
100 µm filtration	❖Excludes all fish, all invertebrates, with the exception of small juvenile forms and all macrophytes	Buchholz et.al.,1998
50 µm filtration	❖Effective against zooplankton and fish	Oemcke, 1999
40 µm filtration	❖Remove all life stages of zebra mussel	Oemcke, 1999
25 µm, 50 µm filter unit	❖95-99 % effectiveness at removal of macrozooplankton, and 70-80 % removal of microzooplankton and phytoplankton	SWRCB-CEPA, 2002
5 mm pre-screen with a 50 or 25 µm filter	❖Successfully eliminates the majority of the zooplankton and some of the phytoplankton	PBWG, 2005
25 µm (Effective size)	❖Remove cysts of some harmful dinoflagellate species (25–87 µm in diameter) ❖Remove ichthyoplankton, invertebrate zooplankton, and the largest phytoplankton and heterotrophic protests	MITSG, 2006
	❖Excludes all fish, all invertebrates, most phytoplankton, and some large forms of aquatic fungi and protozoans. Most cyst stages will also be excluded.	Buchholz et.al.,1998
20 µm filtration	❖Effective against zooplankton, fish, dinoflagellate cysts and attached bacteria	Oemcke, 1999
Media filtration	❖Remove not only all organisms larger than 5 to 10 µm in diameter but also most of the sediment load in the ballast water	CETS, 1996
Mixed media filters	❖Remove particles as small as 1 to 5 µm in diameter	CETS, 1996
Fine-meshed filters	❖Remove pathogens	MITSG, 2006
0.01 µm Membrane filters	❖Effective against viruses and bacteria	Glosten-Herbert, Hyde Marine, 2002
A two-stage system using woven mesh screen filters	❖The first filter would remove most of the larger zooplankton; the second filter would remove most of the smaller zooplankton and most of the large and medium-sized phytoplankton.	CETS, 1996

Table 3.7 Advantages and drawbacks of filtration system

Advantages	***Drawbacks***	***References***
❖Water is pumped into the tanks is that organisms that are filtered out may be retained in their native habitat ❖A back washing mechanism cleans the filters and collects organisms to prevent their accidental release	❖If ballast water is filtered while being discharged, proper disposal of organisms is required to eliminate accidental introductions ❖It requires specialized equipment which may be expensive to purchase and install.	MITSG, 2006
❖Treatment would deep media filters are highly reliable and do not plug rapidly. Monitored easily by measuring the pressure drop or head loss across the media. Installation of deep media filters on board ships would not be a severe problem as a retrofit. An inline media-filtration system is that ballast water would be treated effectively regardless of when it was loaded. Thus, discharge of treated ballast water could occur at any time in any location without increasing the risk of introducing non-indigenous aquatic nuisance species. Deep media filtration systems could be designed for individual ships and ship classes to optimize shipboard use ❖Strainers were found to be relatively compact, simple to operate, and amenable to retrofit on existing vessels	❖When the effective opening of screens is reduced to remove small organisms, such as those in the range of 10 µm, plugging or fouling rapidly occurs ❖Strainers have limited effectiveness because many organisms of concern are smaller than the existing strainer slot sizes and can pass through the treatment system ❖Space constraints for media filtration units were identified as an issue, as were high flow rates during ballast uptake and discharge	CETS, 1996
❖It can provide a practical first-stage treatment solution	❖Viruses and bacteria require membrane filters effective to 0.01 micron. This is extremely small and the membrane technology is quite expensive, requires prefiltration of 50 to 200 microns, and may not be able to provide the flow rates required in a shipboard application. ❖For high flow rates and ballast volumes such as those required by tankers and bulk carriers, filtration systems with automatic backflush capability are probably not practical. ❖For bacteria removal, membrane filters have been found to be considerably more expensive than UV irradiation	Glosten-Herbert, Hyde Marine, 2002
❖ Well established technology will remove a large number of organisms of concern, will remove some sediment, almost certainly the front end to any system, low power consumption and maintenance	❖Can't remove smaller organisms at the throughputs required aboard ship, unlikely to reduce turbidity to any great extent	Hillman et.al., 2004
	❖Back wash cycles took up too much time (especially with the 25 micrometer mesh), and there was significant loss in pressure after the water passed through the system. ❖Crew would be responsible for changing the filters and completing routine maintenance	PBWG, 2005

Cyclonic Separation:

Inactivation Process: The system basically vortexes the water, forcing the heavier particles to the outer portion of the pipe. Once this occurs, then the outer portion of the water can be separated out or the particles can be collected in some type of collection system.

This flow-through centrifugation system accomplishes the separation of solids and organisms through the creation of a strong vortex in the flow as water flows through the machine The centrifugal force concentrates solid particles and large organisms against the outer wall, allowing water to move through the center of the separator.

Sedimentation / Flotation:

Inactivation Process: Sedimentation is achieved by the used of a coagulant which acts to cohere heavier particles which then settle and can be removed by localised pumping. Flotation relies on encouraging particles to form by use of a chemical coagulant. Due to the nature of the coagulant, particles then rise to the surface after attaching to air bubbles which are injected into the water column. Floated residue is then scraped from the top of the tank. In the application of ballast water treatment, sedimentation and flotation are unsuitable for on-board use as these processes rely on a steady free surface. These treatments could be considered for onshore treatment as they both result in approximately 1% residue.

Table 3.8 Advantages and drawbacks of cyclonic seperation system

Advantages	***Drawbacks***	***References***
	❖Can operate at high flow rates and does not result in a large decrease in water pressure after it passes through the system	PBWG, 2005
❖There are no movable parts, no filter elements or screens to clean ❖The system is reported to require little or no maintenance and, if properly designed, could be operated through simple controls ❖Do not affect normal ballasting operations	❖It can not be applied as a single system treatment option ❖Smaller materials such as sediments, micro plankton, bacteria, and viruses will not be separated from the water using this approach.	SWRCB-CEPA, 2002
❖Particularly applicable on the ballast intake cycle where the separated particles can be discharged with a small percentage of the pumped water back into the harbor of origin ❖Either a single very large unit or a bank of smaller hydrocyclones in parallel can be used to achieve the desired throughput. It also may be possible to arrange units in series and optimize each for a different particle size or density ❖It is proven and available technology, has simple retrofit capability, has small impact on existing ship pumping capabilities and provides automatic operation ❖It can be expected to remove entrained particles that are heavier than seawater. This will effectively remove some suspended solids ❖Can provide a practical first-stage treatment solution	❖Should be installed as vertical as possible with the inlet at the top. Can be inclined if overhead space limitations exist, but performance may suffer as they approach a horizontal orientation ❖Not effective in reducing total zooplankton density ❖Not very effective in reducing bacteria, viruses or phytoplankton (chlorophyll a concentrations or algal growth). These organisms are small and neutrally buoyant ❖It does not remove turbidity, especially dissolved materials,	Glosten-Herbert, Hyde Marine, 2002
❖When combined with secondary treatment such as UV, ozone, or other chemical treatment could be effective in removing a wide range of non-indigenous species		PWSRCAC, 2005c
❖Can remove much of the sediments, possibly effective in removing dinoflagellate cysts.	❖Will not remove most organisms since the specific gravity is very close to that of water.	Hillman et.al., 2004

3.3.3.2 Physical Treatment

Thermal (Heat), ultraviolet, ultrasound, electric pulse & pulse plasma, deoxygenation, magnetic fields and acoustic systems are among the alternatives of physical treatment

Thermal (Heat) Treatment:

Inactivation Process: Heat kills aquatic organisms by denaturing cellular proteins and/or increasing metabolism beyond sustainable levels. Death by metabolism shutdown generally occurs quicker and at lower temperatures for more complex organisms.

Options for heating ballast water onboard a vessel include:

1. Use of waste heat produced by the ship's engines, and
2. Use of heat created by auxiliary boiler systems installed aboard the vessel.

Thermal treatment effectiveness is a function of species' tolerances, temperature, and exposure period. Most microorganisms are able to tolerate relatively high temperatures for short periods, and lower temperatures for longer periods.

***Ultraviolet (UV)*:**

Inactivation Prosess: UV treatment triggers photochemical reaction of cellular nucleic acids. When a microorganism is exposed to UV radiation, the energy is absorbed by the organism's DNA. If the organism receives a sufficient number of UV photons in a short period, covalent bonds form between adjacent bases in the DNA. The formation of these bonds prevents the organism's DNA from being "unzipped" for replication, and the organism's cells are unable to reproduce.

Table 3.9 Advantages and drawbacks of heat system

Advantages	*Drawbacks*	*References*
❖Ships have large amounts of waste heat ❖It can be very costly	❖Not very effective particularly against bacteria and pathogens as the normal temperatures (equivalent to the human body temperature)	Mackay, 2005
❖Temperatures to 37-38^{o}C and are effective in killing a majority of non-indigenous species ❖Higher temperatures are required to effectively kill all microorganisms including cysts ❖The length of time ballast water is exposed to target temperatures affects the organism mortality ❖Longer exposure times result in higher kill rates	❖Heating of ballast water may increase system corrosion and promote the growth of algae that thrive in the heat ❖Heating water in ballast tanks of older ships may create serious safety problems due to the unknown effects of local expansion or corrosion ❖Space requirements make heat treatment installation impossible in retrofits and will require careful planning for installation on a new vessel, particularly where additional boilers are required	PWSRCAC, 2005e
❖There are no resulting chemical byproducts	❖May not be as useful in colder waters since more energy would be needed to raise ballast water to the necessary temperature ❖Require the installation of pipes to bring the ballast water in contact with heat ❖It may be necessary to be filter out dead organisms before releasing the heated ballast water into the environment	MITSG, 2006
	❖Larger ships and ships with cold water shipping routes might not be able to raise the temperature of the ballast water high enough to kill the majority of organisms ❖A more efficient heat exchanger would probably have to be installed, and there would be additional costs for burning excess fuel that would be required to raise the temperature of the ballast water to the appropriate level	PBWG, 2005
	❖Some voyages will be too short to permit heating the water to the required temperature or holding the temperature for the required period ❖There is a limited amount of energy available from waste heat sources	CETS, 1996
❖Many organisms (including some cysts) are rendered ineffective by heat, source of heat is taken from waste from engine	❖Heat budget may not allow ballast to be elevated to a suitable temperature, may not be effective in cold situations, ensuring all water is exposed is problematic, may be structural implications for the vessel	Hillman et.al., 2004
❖The crew would only need minimal training to operate the equipment	❖Pipes conducting heated fluid are typically insulated to prevent loss of energy and to protect crew members ❖Thermal pollution may occur if large volumes of heated water are discharged into receiving waters, causing localized thermal effects on the immediate aquatic environment ❖Air pollution problems may occur if heat-generating equipment needs to be operated during extended periods of time in order to heat ballast water to required temperature	SWRCB-CEPA, 2002

Table 3.10 Advantages and drawbacks of ultraviolet system

Advantages	*Drawbacks*	*References*
❖For short-lived microorganisms (e.g., viruses, bacteria, and protists), this means that a sufficiently dosed community of microorganisms will die during or soon after treatment	❖If exposure is insufficient to kill all of the organisms, genetic mutation of surviving individuals, as well as subsequent generations, is possible.	Buchholz et.al., 1998
❖In wavelengths from 200 to 280 nm can effectively inactivate bacteria, viruses, and other living organisms. ❖UV treatment can be accomplished both during ballasting and deballasting. This greatly improves the biological effectiveness of the entire treatment system ❖Capable of automatic operation with electronic monitoring and alarms. ❖UV light does not change the physical characteristics of the treated water and is environmentally friendly with no known toxic by-products, residuals or lasting effects.	❖UV creates only a small pressure drop and requires simple piping connections	Glosten-Herbert, Hyde Marine, 2002
❖Well established technology, used worldwide for purification, effective against pathogens, low maintenance, no residuals.	❖Effectiveness lowered by turbidity and colour.	Hillman et.al., 2004
❖A good candidate for a secondary treatment system	❖This system can operate at high flow rates and does not result in a large decrease in water pressure after it passes through the system	PBWG, 2005
❖Does not change the physical characteristics of the treated water ❖Environmentally friendly with no toxic byproducts or residuals.		Mackey, 2005
❖Very effective technology for ballast water treatment. ❖Most effective on microorganisms, so would need to be combined with another method to effectively remove all potential bioinvaders from ballast water	❖Ineffective in water containing suspended matter, so ballast water may need to be filtered before treatment.	MITSG, 2006
	❖Some species of algae, spores and cysts are more resilient to UV treatment ❖UV generating equipment has failed under the harsh environmental conditions on board a ship.	Larsson & Systma, 2006

Ultrasound:

Inactivation Process: Acoustic systems use transducers to apply sound energy of specified amplitude and frequency to water to be treated. Ultrasonic systems use transducers to convert electrical energy into vibratory energy of a specific amplitude and frequency. When this energy is passed through liquid, microscopic gas bubbles quickly form, expand, and implode. In the area immediately surrounding the bubbles, there are extreme temperatures and pressures, which increase chemical reactivity, polymer degradation, and free-radical production. Exposure of aquatic microorganism to ultrasonic treatment results in cellular disruption and organism death.

Table 3.11 Advantages and drawbacks of ultrasound system

Advantage	***Drawbacks***	***References***
❖Ultrasonic frequencies around 20 kHz kill or inactivate bacteria and fungi ❖High-intensity acoustic sources can shatter the shells of juvenile zebra mussels and lead to the lethal disintegration of veligers ❖Lower frequency acoustic signals deter fish, although the deterrent frequency is species dependen	❖Ineffective in higher organisms	CETS, 1996
❖Small organisms and the cell walls of larger organisms are ruptured by the frequency of the ultrasonic energy, causing death to the target organisms		SWRCB-CEPA, 2002

Electric Pulse & Pulse Plasma:

Inactivation Process: In both pulsed electrical field technology and pulse plasma technology short burst of energy are used to kill organisms in water. The difference between the two technologies is how the energy is created, but essentially the effect on organism mortality is the same.

In pulsed electrical field technology, water is passed between two metal electrodes. The water is subjected to an electric pulse which produces short energy bursts at a very high power density and pressure. The energy generated, and transferred to the water, is strong enough to electrocute an organism. If used in a ballast water application, the transfer of energy would theoretically kill the non-indigenious species.

Pulse plasma technology operates in a similar manner by delivering a high energy pulse to mechanism that is placed in the water. A plasma arc is generated in the water. The energy created by the plasma arc destroys the organism.

Table 3.12 Advantages and drawbacks of electric pulse and pulse plasma systems

	Advantages	*Drawbacks*	*References*
Electric Pulse	❖Electric pulse system is automated and does not require attended operation	❖The risk to the crew and the expense and size of the equipment needed to generate these pulses are the major drawbacks to this method of ballast water treatment	CETS, 1996
Electric Pulse & Pulse Plasma	❖Does not produce toxic chemical residuals or generate chlorine ❖The mean time between equipment failures is long ❖Long lifetime and low maintenance	❖Large energy sources would probably be needed for systems capable of treating large volumes of ballast water ❖The costs of developing the system suitable for shipboard application is likely to be high, with resulting high equipment acquisition costs ❖Repair can be achieved by replacement	CETS, 1996
Pulse Plasma	❖Remove aquatic fouling organisms such as Zebra mussels, alga colonies, and bacterial growth	❖Shock wave is powerful and over time could lead to materials failure or enhanced corrosion, resulting in damage to the piping in a ballast water system ❖Require training to operate and maintain ❖Equipment malfunctions might be beyond a crew's ability to repair while at sea, which could lead to not having the treatment equipment available for extended periods of time	SWRCB-CEPA, 2002
	❖Pulse plasma system is automated and does not require attended operation	❖Pulse power system would generate gaseous decomposition products, notably carbon dioxide	CETS, 1996
	❖	❖A shock wave could affect the integrity of the pipes and the tank walls ❖A loud sound is also produced that could be harmful and/or annoying to the crew	PBWG, 2005

Deoxygenation (Oxygen Deprivation):

Inactivation Process: This treatment accomplishes the removal of ballast water organisms by extracting the dissolved oxygen from ballast water. This can be accomplished by;

1. purging the oxygen from the ballast tanks with nitrogen through the use of chemical additives,
2. use of a vacuum chamber over time.

Table 3.13 Advantages and drawbacks of deoxygenation

Advantages	***Drawbacks***	***References***
❖Toxic to a range of fish, invertebrate larvae, and aerobic bacteria	❖Ineffective against anaerobic bacteria and cyst and spore stages, including dinoflagellate cysts	CETS, 1996
❖Nitrogen treatment is reported to be safe with the proper equipment and training ❖The treatment would be partially effective, causing substantial mortality of ballast tank organisms that are not adapted to low oxygen environments ❖It may be cost effective because it could decrease the rate of corrosion in ballast tanks ❖Reduction in the survival rated of polycheate worms, green crabs, and the zebra mussel ❖Several hours or longer certainly will kill most metazoans ❖A prototype study involving a 72-ton per hour high speed ballast water treatment system fitted with a vacuum chamber showed an immediate kill of live zooplankton ranging from 50 to 75 percent and nearly complete reduction within two days of treatment	❖It will have little effect on those bacteria and protists with metabolic systems that have evolved to routinely switch between toxic and anoxic environments	SWRCB-CEPA, 2002
❖Deoxygenation studies show good success in killing a variety of aerobic non-indeginous species within hours to days	❖ Nitrogen sparging (bubbling) would require extensive retrofitting in existing ships	PWSRCAC, 2005f
❖Removal or reduction of oxygen will eliminate or reduce direct oxidation reactions related to corrosion ❖Copepod crustaceans and shallow water and estuarine species that are unable to withstand 24 hours of exposure to hypoxia		Tamburri, 2003

Magnetic Fields:

Inactivation Process: Strong magnetic forces interfere with organism pH levels, which in turn support the cell's organelles and proteins. Magnetic forces also interfere with the flow of ions in the cell membrane, resulting in death. A typical magnetic system consists of a magnet or electromagnet attached to the piping system.

Table 3.14 Advantages and drawbacks of magnetic fields

Advantages	***Drawbacks***	***References***
❖Effective against Calcareous shell-forming invertebrates such as Zebra Mussels		SWRCB-CEPA, 2002 & CETS, 1996
❖Effective against single cell bacteria, yeast and fungi ❖Reduces oxygen saturation levels in treated water. This reduces corrosion in pipes ❖Treatment system may be feasible since there are magnetic treatment units currently in use to treat marine fuel oil systems ❖The units are typically constructed of stainless steel in order to resist corrosion ❖The units themselves are robust enough for marine operation and can be designed to fit within confined ships' engine spaces. ❖The maintenance for these systems is minimal. The units do require periodic monitoring to ensure proper operation. ❖Crew training would be required because maintenance is necessary after prolonged use. ❖These units can be compact and would require little or no energy to operate	❖It could pose a potential hazard to marine life in the immediate area where the treated water is discharged	SWRCB-CEPA, 2002

3.3.3.3 Chemical Treatment

Biocides, anti-fouling coatings, pH adjustment and hyper salination are among the alternatives of chemical treatment.

Biocides:

Means of Application: Biocides could be applied in two ways:

1. Concentrated solid or liquid chemicals could be added to ballast water in certain ratio. The amount of premixed liquid biocide could be added via feeding lines to the main line with the main ballast pumps. By means of the turbulation of the pumping systems, complete mixing of biocides can be realized. As a result, the target organisms shall be inactivated.

2. It could be generated electrolytically from sea water.

The effective applications of biocide concentration for aquatic nuisance species have been assumed by CETS (1996) in the range of 1 to 5 mg/l (ppm). CETS also states the importance of contact times and dosage for effective treatment results. However, if doses are similar to those used for waste-water treatment, only 5 m^3 of biocide would be required for each million cubic meters of ballast water to give a 5 mg/l biocide concentration. Therefore, even large ships carrying thousands of cubic meters of ballast would be required to carry only a few cubic meters of biocide per voyage.

Table 3.15 Affected organisms via biocide

	Affected organisms	*References*
Oxidizing Biocides	❖Hydrogen peroxide was effective against zooplankton and the bacterium Vibrio fischeri	Dobbs & Rogerson, 2005
	❖Ozone levels of 0.4 ppm have been reported to control most vertebrate species, unicellular & some benthic organisms ❖Control of more resistant cysts can be achieved at ozone levels of 10 ppm ❖Ozonation treatment killed more than 99.9 % of the bacteria after five hours of ozonation and over 90 % of the zooplankton after ten hours	SWRCB-CEPA, 2002
Non-oxidizing Biocides	❖Glutaraldehyde was effective against zooplankton and the bacterium Vibrio fischeri	Dobbs & Rogerson, 2005
	❖24-hour exposure to copper sulfate, an algicide, at concentrations of 200 parts per million (ppm) up to 10,000 ppm at varying levels of pH and salinity was found to be ineffective in killing dinoflagellate cysts ❖Chlorine tested at 10 to 2000 ppm, and hydrogen peroxide tested at 100 to 60,000 ppm were found to be effective only at high concentrations ❖Acrolein® detected no viable motile dinoflagellates in any Acrolein® treated samples and a significant reduction of test bacteria samples with the lowest concentration of Acrolein® used ❖Seakleen® to a wide variety of marine and freshwater aquatic organisms representing major taxonomic groups indicated that a high degree of toxicity was achieved with the administration of low concentration of the biocide	SWRCB-CEPA, 2002

Table 3.16 Advantages and drawbacks of biocide

Advantages	***Drawbacks***	***References***
❖Effective to inactivate broad range of organisms ❖Have quick decay rate	❖Lead to corrosion in the tanks	PBWG, 2005
❖Shipped and stored in concentrated solid or liquid forms ❖Easy to store onboard a ship ❖Ease of application ❖Application units are reliable and need little maintenance ❖Training the crew could be relatively simple	❖Selection of the biocide should be carefully chosen to avoid negative impacts on human/environment ❖Dimensions of applying unit may be a limitation when installing aboard ships ❖Precautions from biocides is the necessary for users safety	MITSG, 2006
❖The use of pre-filtration (to about 150 μm) can significantly reduce the chemical concentrations required for effective treatment. ❖Biocidal treatments are believed to be a technically and financially feasible method for treating residual ballast sediment in tanks	❖It may be very difficult to obtain approval for the use of chemicals by ships where the dosage cannot always be carefully monitored and the holding time guaranteed ❖Risks of chemical exposure to the ship's crew must be addressed with proper safety procedures.	Glosten-Herbert, Hyde Marine, 2002
❖Treated water might not pose a substantial environmental hazard if it were discharged in large quantities.	❖Uncertain effectiveness of biocides in achieving inactivation of the target organism(s) ❖Compliance with discharge regulations for such chemicals in certain areas of the world	CEST, 1996
❖Dosages between 1 and 5 parts per million (ppm) are necessary with some "shock-dosages" of up to 10,000 ppm required to achieve destruction of microbial non-indigenous species	❖Retrofit requires installation of stainless steel or other corrosion resistant storage, handling, and distribution piping	PWSRC, 2005
❖Some of biocides degrade into non-toxic chemicals within a few days ❖Acroline little or no new equipment would be needed to apply non-oxidizing biocides	❖Because of the time needed for deactivation, non-oxidizing biocides may not be the best option for shorter voyages	SWRCB-CEPA, 2002

Two general types of biocides exist: oxidizing and non-oxidizing.

Oxidizing Biocides:

Inactivation process: Oxidizing biocides act by destroying cell membranes which leads to cell death is hazardous for organisms. Oxidizing biocides include, but are not limited to, chlorine, bromine, iodine and their multiple compounds, chlorine dioxide (ClO2) and hypochlorites (e.g., NaOCl), hydrogen peroxide(H2O2), ozone (O3) and Paraclean® peroxy acetic acid. MITSG (2006) compromise that the toxic byproducts produce when the oxidizing agent react with sea water, consequently causing negative environmental impacts at the discharge site.

Chlorine: Chlorine is produced by passing an electrical current through water containing chloride ions the so called system named as electrolytic chlorination.

Ozone (O_3);

1. is naturally produced during lightning storm discharges,
2. is naturally continuously occurring in the stratosphere by ultraviolet action,
3. can be artificially produced by the action of high voltage discharge in the presence of air or pure oxygen (O_2).

Non-oxidizing Biocides:

Inactivation process: Non-oxidizing biocides act by interfering with a necessary life function such as metabolism or reproduction (the physiological and metabolic processes of organisms). Most pesticides fall into this group of chemicals as the group of gluteraldehyde-based chemicals. Non-oxidizing biocides include, but are not limited to, such compounds as Acrolein®, Seakleen®, Peraclean® Ocean, tributlytin, dissolved copper, dissolved silver, glutaraldehyde, and organic acids.

Table 3.17 Advantages and drawbacks of different oxidizing biocides

	Advantages	*Drawbacks*	*References*
Chlorine	❖Effective against most viruses and bacteria		PWSRC, 2005
Chlorine	❖Units are comparatively small ❖Prevent biofouling ❖Various forms of chlorite (calcium hypochlorite or sodium hypochlorite) used to treat ballast water	❖Gas form of chlorine not proper for enclosed spaces ❖Addition of chlorine to seawater generates toxic byproducts	CETS, 1996
Chlorine	❖Chlorine is inexpensive and effective as a disinfectant for ballast water	❖Most areas will require dechlorinization prior to discharge, an expensive process ❖Can cause corrosion in tanks and may react, particularly with salt water, to form other undesirable compounds	Mackay, 2005
Chlorine Dioxide (ClO_2)	❖An oxidizer similar to chlorine and is effective against cysts, bacteria, and viruses	❖ClO_2 is more costly than chlorine	PWSRACAC, 2005b
Hydrogen Peroxide	❖A strong oxidant capable of destroying 100% of cyst stage non-indegineous species at high doses ❖Hydrogen peroxide degrades to oxygen and water, making its residual impact very low	❖Hydrogen peroxide is extremely corrosive, creating a potential safety risk	PWSRCAC, 2005b

Table 3.18 Advantages and drawbacks of ozone

Advantages	***Drawbacks***	***References***
❖Ozone was thought to be the primary disinfection agent	❖Ozone subsequently became apparent that bromide in seawater was being converted by ozone to hypobromite ion and hypobromous acid, a less effective, but longer lasting disinfectant ❖Long contact times (hours to days) were required for effective treatment	Kazumi, 2007
❖The high oxidation potential of ozone increases kill rates of fungus, bacteria, and viruses ❖In low concentrations (0.05 ppm) it imparts a sweet odor ❖Effective at killing microscopic organisms	❖Unstable gas that quickly decomposes to oxygen ❖Ozone generators requires about 10 hours of maintenance per month ❖Large capacity ozone generation units are complex and bulky ❖Ozone is very reactive and corrosive and requires corrosion resistant materials ❖Prolonged exposure to high levels (> 100 ppm) can produce headaches and nausea. ❖Retrofitting older ships could prove costly due to the space available for installation and piping reconfiguration. ❖Not as effective at eliminating larger organisms ❖Reactions between ozone and components of sea water may also result in toxic chemicals that should not be released into the environment	SWRCB-CEPA, 2002
❖No chemicals or side effects	❖Very fast reaction with bromide in seawater means effectiveness will be minimal	Hillman et.al., 2004

Table 3.19 Advantages and drawbacks of non-oxidizing biocides

	Advantages	*References*	*Drawbacks*	*References*
Gulteraldehyde	❖Research indicates use of glutaraldehyde may be most effective for one-time disinfection of small vessels.	PWSRCAC, 2005b	❖Glutaraldehyde is highly corrosive in concentrated form creating a potential health and safety risk. ❖Large scale use aboard a tanker is expected to be cost prohibitive.	PWSRCAC, 2005b
	❖Sediments sampled from NOBOB (No Ballast On Board) ships resulted in a recommendation that a concentration of at least 500 mg/L of glutaraldehyde held for 24 h, would be effective in killing 90 % of organisms, volume of 200 metrictons ship	Kazumi, 2007		
	❖Being metabolized quickly when released in the environment to carbon dioxide, a safe chemical	SWRCB-CEPA, 2002		
SeaKleen®	❖Cost effective - 10 to 20 cent per tonne ❖Highly soluble in fresh and salt water ❖Not corrosive to piping or ballast tanks ❖Delivered in safe powder form (no special training) ❖Low affinity for particulate matter and sediment ❖Particularly suitable for bulk carriers and tankers with large ballast volumes ❖Naturally degrades and is quickly diluted to non-toxic levels Straightforward dosing under all ballasting conditions including gravity ballasting	Hyde Marine Inc., 2006	❖Exposure of SeaKleen® to sunlight reduced the toxicity of the compound such that after 72 h of light exposure, SeaKleen® was not biocidally effective.	Kazumi, 2007
Peraclean®	❖Highly effective (99 - 100 % mortality) even for resilient organisms such as toxic dinoflagelate cysts ❖Efficacy fulfills the new IMO criteria for the groups of small-sized and large-sized organisms ❖Short half-life after application to ballast water ❖No toxic chlorinated organic compounds are formed ❖Peraclean® Ocean neither increases corrosion nor the damaging of the ballast water tank coating ❖Liquid and easy to apply (e.g. injection during ballast water intake) ❖Short reaction time of only 1-2 days required ❖Applicable in marine, brackish and fresh water Applicable even in muddy water and in water with a high content of organic matter	Evonik Ind.	❖One limitation of this technology was the need to store chemically treated effluent for at least 6 d before discharge was considered safe, and calculated that an extremely large storage capacity (> 120 m^3) for holding the effluents would be required if the technology was conducted on a full scale (water flows of 530 m^3/ h)	Kazumi, 2007

Anti-fouling Coatings:

Inactivation Process: A coating could be formulated that was highly loaded with toxic material and would release lethal concentrations of biocide into the water. Basically, two types of anti-fouling paints could be used ballast tanks:

1. a nonstick type, silicon-based paint that would prevent organisms from attaching to the surface of the tank,
2. a biocidal anti-fouling paint that would release small amounts of biocide at the coating surface to kill attaching organisms.

Table 3.20 Drawbacks of anti-fouling coatings

Drawbacks	*References*
❖Would have a short lifetime, and the treated ballast water would probably be toxic and require treatment prior to discharge	CETS, 1996
❖Paint coatings could only act on benthic organisms, leaving species in water columns unharmed ❖The durability of the coatings tentative ❖Reapplication would be needed to maintain an effective level of protection ❖Biocidal coatings would ultimately release residual biocide into receiving waters	SWRCB-CEPA, 2002

Ph Adjustment:

Inactivation Proccess: Sudden changes in pH, and the addition of an acidic or alkaline compound to increase or decrease the pH of ballast water has been considered as a method of disinfecting ballast water. The corrosion rate of carbon steel is not influenced by pH over the range of 4.5 to 9.5 in distilled and tap water. Below pH 4.0, hydrogen evolution begins and corrosion increases dramatically.

Table 3.21Drawbacks of pH adjustment

Drawbacks	*References*
❖Corrosion resulting from lowered pH would present problems in the maintenance and operation of ballast water treatment systems ❖Treating ballast water with large doses of lime to achieve increases in pH may also result in corrosion ❖Some species of dinoflagellates are unaffected by changes in pH	PV, 2002

Hyper salination:

Inactivation Proccess: Hyper salination involves the addition of large quantities of sodium chloride (salt) to ballast water to create a super-saline environment. The sudden increase to extreme levels of salinity destroys cells through dehydration.

The addition of freshwater to salt water dramatically reduces water salinity causing tissue destruction in some organisms through osmotic swelling. This method is unlikely to be practical or economically viable due to the large quantities of freshwater required and associated pumping and piping needs.

Table 3.22 Drawbacks of hyper salination

Drawbacks	***References***
❖Possible corrosion of ballast tanks may occur due to the large quantities of salt needed ❖Unlikely to be a viable solution in the treatment of ballast water particularly in the case of older vessels where tank coatings may not be intact ❖The estuarine organisms commonly found in ballast tanks are tolerant to wide fluctuations in salinity thereby reducing the effectiveness of this treatment	PV, 2002

3.3.4 On-shore / Port-based Treatment Alternatives

States must take necessary and adequate measures – mostly non-profit - in order to protect their territorial waters. The measures on on-shore ballast water reception and treatment facilities shall be taken into consideration.

The purpose of the alternative, suggested in the "Guidelines for Ballast Water Reception Facilities", adopted by IMO in October 13, 2006, is stated as follows: "These guidelines are not intended to require that a Party shall provide such facilities. The guidance is also intended to encourage a worldwide uniform interface between such facilities and the ships without prescribing dedicated shoreside reception plants".

Currently, the Party states are not imposed with the liability of establishing on-shore ballast reception and treatment facilities. However, following the entry of the Convention into force, some defects and failures may occur in the practice, possibly making these facilities mandatory in the medium term.

The establishment of on-shore ballast reception facilities is expected to serve for several primary concerns:

- ❖ An alternative for vessels that are not equipped with one of the on-board ballast water treatment systems, during the transition period until 2016, not to discharge their ballasts into the sea,
- ❖ A possible alternative in cases where fitting/retrofitting an on-board treatment system to the vessel is not possible, due to criteria such as age and condition of the vessel,
- ❖ A possible alternative in cases where the space in the engine/pump room is inadaquate to establish an on-board treatment system, or the treatment system is incompatible with the equipment of the ship,
- ❖ An alternative to prevent ships discharging their ballasts into the sea, in unfavourable air/sea conditions when they are unable to make exchange,
- ❖ An alternative as a support unit in cases of failure in the on-board ballast water treatment system that is equipped to the ship, or when the system is not operating efficiently.

On-shore treatment could be conducted ashore or on a treatment ship. Nowadays, research and experiments focus at three different alternatives:

1. On-shore reception and treatment facility:

Coastal areas are multi-sectoral areas. These areas, offering numerous possibilities, natural beauty and richness are areas where each stakeholder wishes to make the most of profit. Undoubtedly, port facilities established in such areas bring along large investments. Therefore, every single part of these extra-valuable port areas should be utilized in the most productive way. The projected establishment of the ballast water treatment facility would produce dead space in the port where each parcel is necessary and planned, or the designed facility will be limited in size. Because of these reasons, establishing the facility outside of the port area is a relevant alternative.

2. Mobile reception facility with on-shore treatment facility.

3. Mobile reception and treatment facility:

Gollasch (2002 & 2006) suggested in his research to use a tanker (e.g. a phased out single hull tanker) or barge as floating ballast water reception facility. He also discussed that although this will provide flexibility to the ballast water operations in the port, this method is only relevant with limited number of berths.

On-shore reception and treatment systems are considered as a decent alternative, since they take in and treat large amount of ballast water from many ships simultaneously. However, since the ballast water is not commercial good – for the time being having no economic value when treated, though costy- it is necessary to plan, design and equip the reception and treatment facilities with minimum investment and operating costs. However, some researchers still argue that a on-shore system to be established on port, is more economic than establishing on-board treatment systems on each ship.

Any kind of on-board ballast water treatment alternative can be implemented in a ballast water treatment facility established on-shore, treatment technologies used in wastewater treatment systems can also be applied. Conventional methods in wastewater treatment systems include filtration, sand filter, sedimentation tank, etc. Conventional systems that are known and verified for ease-of-use and results are expected to be relatively more economic. Thus, treatment of ballast water in large amounts would also be more economic in this respect.

A treatment facility to be established on-shore will have many advantages, as well as drawbacks, like in any other treatment alternative. Table 3.23 shows the positive and negative aspects presented by scientists and researches following their review of this management alternative.

Some of the points to be considered for the effectiveness of on-shore treatment practices are as follows:

1. Storage of ballast water before and after treatment, in accordance with the quarantine regulations,
2. Existence of an accredited laboratory in each port where a reception and treatment facility is established, to test and analyze the ballast water, sampled from ships,
3. Preparing regional, national and local legislation, about the operation of reception and treatment facilities.

Table 3.23 Advantages and drawbacks of on-shore treatment system

Advantages	*Drawbacks*	*References*
❖Cheaper than treatment conducted on each ship ❖Treatment standards can be guaranteed and enforced ❖Eliminates concerns about crew safety or wear or stress on the ship ❖Fewer space and power constraints (versus on-board treatment) ❖Treatment managed by water treatment professionals rather than ship's crew. Maintenance of equipment and operation of treatment process likely to be more consistent and reliable than in the more variable and sometimes difficult conditions on-board ❖Deposited and suspended sediments and organic material may be removed by gravitational settlement or media filtration ❖Mortality of organisms due to additional holding time ❖Economies of scale in constructing and operating relatively few on-shore treatment plants versus plants on board each ship ❖Easier monitoring and regulation of the treatment process and effluent quality ❖Resting stages (cysts, spores, etc.), which are the forms most resistant to treatment, may similarly be removed	❖Residuals will need to be managed ❖Demurrage and increased ship hire costs due to delay ❖Vessels may not be able to keep their ballast on-board due to tides and draft requirements in approaching port ❖The land area required for holding ponds or tanks is not easily accessible at all ports ❖Difficulty involved in getting ballast water ashore ❖Cost of retrofitting infrastructure to ports for the receival of ballast water ❖It is dependant on the ships master being prepared to keep all ballast on-board, rather than discharging during approach to port ❖High cost of land for treatment plant in some areas (although a floating "treatment ship" may offer an alternative at reasonable cost) ❖No treatment of ballast water discharged prior to ships' entry into port (such as when a ship must lessen its draft before crossing a shallow bar or entering a shallow port)	Oemcke, 1999
❖Attractive for oil tankers in some cases where ship infrastructure already exists to handle dirty ballast water in shore based treatment plants.	❖Costs, limited availability, treatment quality control and practical difficulties will impose severe restrictions on further development and likely widespread implementation of such options	Taylor & Rigby, 2001
❖Proper and economic disposal of treatment process waster under the oversight of the port authority of other state or federal agencies	❖The inability to accommodate varying trade routes and vessel types ❖Require docks and vessel to be fitted with ballast water discharge manifold piping ❖Shipping delays could result if the treatment plant is out of service ❖The land cost can be significant driver in well-developed ports	PWSRCAC, 2005a
❖All tankers have standardized piping and manifolds for cargo transfers and the concept of standard fittings is embedded in ship design and construction so this could easily be achieved provided to cargo transfer pipes may be used for ballast waster discharge.	❖In larger ports, additional pipework may need to be installed at each pier and also storage facilities for large volumes of water need to be available.	Gollasch et.al., 2007

CHAPTER FOUR
DESIGN OF AN ON-SHORE BALLAST WATER RECEPTION AND TREATMENT FACILITY

Tankers are the major expected customers of on-shore reception and treatment facilities that are planned to be established, since they transport very large amounts of cargo and consequently ballast. Therefore, this chapter attempts to identify the optimum capacity of a reception and treatment facility which can be established in a refinery port.

A refinery port is selected in Aliaga region as study area where tankers with large ballast and cargo capacity berth. Aliaga, a county of Izmir city is located between 38^0 56' N, 37^0 S latitude and 26^0 53' W, 27^0 10'E longitude which is a developing industrial region (figure 4.1). In the region, there are 2 refineries (Tupras and Petkim A.S), Iron and steel plants with different capacities (Habas, Ege Celik, Izmir Demir Celik, Cebitas, Sider Demir Celik, Ozkan Demir Celik, Eregli Demir Celik, Kocaer Haddecilik etc.), energy station (Izmir Enerji Dogalgaz Cevrim Santrali), several port facilities and their related industries are situated. Establishing an on-shore ballast water reception and treatment facility in the region where intensive port operations take place is thought to be a right step to keep the ballast water discharged from the ships under control.

In order for the on-shore treatment facility to serve for all vessels coming to the port with full-capacity ballast, the treatment facility should be designed in infinite size. However, a treatment facility in infinite size is not expected to be economically feasible. The primary criteria to be considered in the design stage are the number of vessels in various sizes, ballast operation time and the amount of ballast they would discharge.

The thesis introduces a projection of a treatment facility design, by using the data obtained from a refinery port and determining the estimated amount of ballast operations in that port.

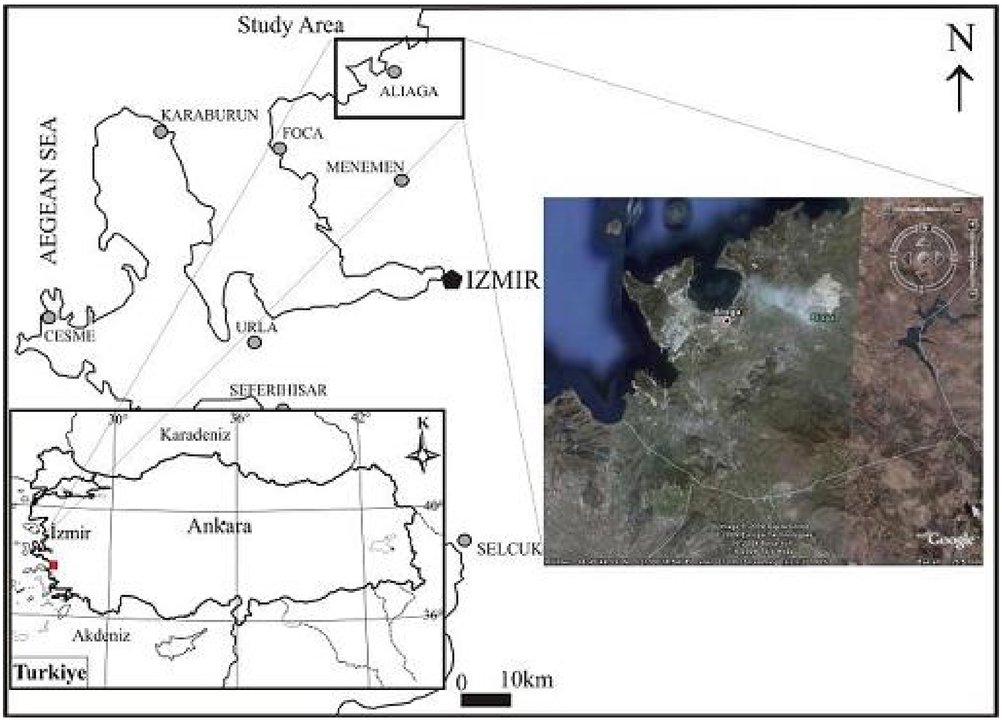


Figure 4.1 Location map of the study area

The difficulties in gathering data are discussed in the dissertation. Chapter five briefly discusses the progress made in Turkey, prior to the entry of the Convention into force. At this stage, Ballast Water Reporting Form (Annex III) has been prepared, which aimed at collecting data about the vessels coming to Turkish ports and the ballast water they bring, via a web site (lodos.mam.gov.tr/liman), to be used by Harbour Masters. During this study, the accuracy of the information which the shipping agencies have recorded the data on this web site has been compared with the data obtained from various institutions and by way of personal interviews. However, it is found out that the data provided through institutions and persons do not match with the data in the web site, and most of the data in the web site have been entered inaccurately or incompletely (personel interviews with pilots and port state control officers).

Table 4.1 Summary table

Period of the data set	July 01, 2007- December 31, 2007
Data gathered from	❖ Oil Refinery Port Facility – Aliaga ❖ Harbour Master of Aliaga (personel interview) ❖ Ballast water reporting program of Harbour Master (lodos.mam.gov.tr/liman) ❖ Pilot of Aliaga Port (personal interview)
Gathered data	❖ List of tankers incoming with ballast water ❖ List of tankers incoming with cargo ❖ Gross tonnages of all incoming tankers ❖ Ballast capacities of all incoming tankers ❖ Amount of ballast discharged by incoming tankers
Steps of data analysis	❖ Raw data analysis ❖ Transforming into daily basis ❖ Transforming into timely basis
Method	1st Phase: Identifying of statistical distribution fitting with data. 2nd Phase: Establishing new data sets to match with the identified distribution (generating new data set for discharging and loading stage). 3rd Phase: Capacity modelling according to the new data set.
Instruments used	❖ Easy Fit - Distribution Fitting Software ❖ SPSS - Statistical Package for the Social Sciences ❖ MS Office Excel ❖ Mass Curve (Rippl diagram) Method
Assumptions 1 (Personel interview with Pilot Cpt. Muhittin GUNDAY, Pilot Cpt. Kasım SUCU & Chief Eng.Ethem Erdem UNER)	❖ Dwt; calculated as 40% more of Grt. ❖ Ballast capacity; calculated as 1/3 of Dwt. ❖ All berthing tankers (except at crude oil loading dock) discharge ballast water. ❖ Incoming tankers berthed with full capacity ballast.
Assumptions 2 (Others)	❖ No differentiation is made as to the navigation area of the tankers that discharge ballast. ❖ The list also includes tankers engaged in coastal voyage. ❖ Each arrival of the tankers that engages in regular voyage is counted, since they discharge ballast every time they berth. ❖ Incoming tankers do an equal amount of ballast operation from the moment they board until the moment they depart. ❖ Operations are continuous and uninterrupted.

4.1 Analysis of the Data

In a refinery port in Izmir, Aliaga region as a study area, tankers berthing to the port with different gross tonnages and the amount of the ballast water they discharge / load during the period of six months are calculated by using the gathered data in the frame of the accepted measures in the table 4.1.

The analysis process of data is given in 3 steps.

Step 1: Raw data analysis

Step 2: Transforming into daily basis

Step 3: Transforming into timely basis

Two different statistical programs are used in the analysis as it is seen in table 4.1. MS Office Excel program is used to calculate the data which are obtained from statistical programs.

- ❖ To identify the statistics of data, SPSS (Statistical Package for the Social Sciences) computer program is used.
- ❖ To identify the distribution of data and generating random numbers, Easy Fit Distribution Fitting Software Version 5.0 is used.

4.1.1 Step 1: Raw Data Analysis

In the 1st step, the amount of ballast water discharged from tankers and loaded from the sea is researched to figure out the conformity of the statistical distribution. The research is made in daily bases for incoming ships and their discharged or loaded ballast water and in spite of the transformations of the data, the outcome of the distributions did not comply with any identified statistical distribution.

4.1.1.1 Analysis of discharging ballast quantity

The research was made on the raw ballast water data which was discharged from 365 tankers, it isdetermined that, the mean is 4231.97 , median is (which means the middle value in a given sequence of data) 1894.67 and the standard deviation is 6423.42 (table 4.2). The 75% of the data is below the value of 2392.60. This shows that the incoming tankers discharge ballast water under the value of 2392.60. This situation is supported by data which accumulate between 0 and 4000 as shown in figure 4.2. The distribution is uneven. Consequently fitting of raw data in any distribution is not possible.

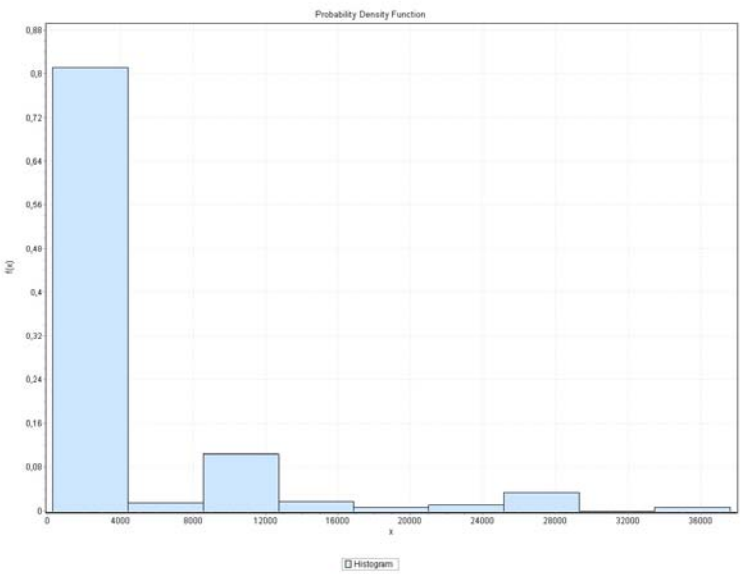


Figure 4.2 Probability density function of raw data of ballast discharging capacity

4.1.1.2 Analysis of loading ballast quantity

Similarly the research on the ballast water loading operation on 51 tanker's, as it is seen in the table 4.2, it is determined that, the mean of data is 16467.45, its median is 16008.00 and standard deviation is 7605.53.

The 75% of the data is below the value of 23657.00. As in the figure 4.3 data points out an even distribution between 0 and 32000. But, the distribution is uneven between 34000 and 40000. Thus, fitting of raw data in a specific distribution not matched.

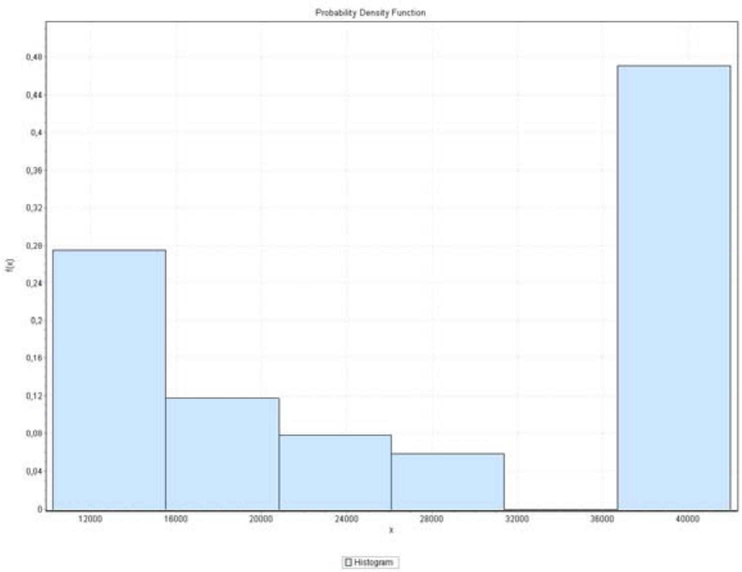


Figure 4.3 Probability density function of raw data of ballast loading capacity

4.1.2 Step 2: Transforming into Daily Basis

At this stage, considering the difference in the amount of ballast water discharged / loaded by each tanker and duration of their operation, data is evaluated again in the time scale. The number of operation days is taken instead of the numbers of tankers operating ballast water as observation number (Table 4.2).

The daily data are used for analyzing the duration of ballast water operation. It is assumed that all the incoming tankers operating an equal amount of ballast water from the moment they arrive until the moment they depart and also it is assumed that the operations are continuous and uninterrupted. For this reason, the hourly data used in the analysis is converted into metric system and divided in to 24 hours. Thus, the standardization of the operation time of the tankers is obtained.

The majority of tankers' completing the operation in less than 24 hours made the calculation easy. A method is developed for determining the daily amount of ballast water discharged / loaded by each tanker when the operation is done between 24 to 48 hours. In the accepted data frame, when operation time is over 24 hours, the left over ballast is transferred in to the second day thus 1 day calculation is obtained. The same calculation system is applied when the operation is completed between 48 and 72 hours, the left over ballast is transferred to the second day as the 2nd day amount, and left over ballast is transferred to the third day as 3rd day amount, the same calculation method is applied to the operations lasting over 72 hours. This way, the total amount of daily ballast discharged / loaded by each tanker coming in different days in the period of 6 months is calculated.

Total amount of daily ballast which is suitable for a continuous distribution is determined. These statistical distributions' suitability is checked through 3 different test (Kolmogorov-Smirnov, Anderson-Darling and Chi-Squared tests).

- ❖ Kolmogorov-Smirnov and Anderson-Darling tests are non-parametric and distribution free tests stands for median. It is robust so it gives best results when the number of observations is below 30. Power of these tests is greater than their parametric alternatives. But in this case, because of the number of observations are greater than 30 - guarantied by CLT (Central Limit Theorem) - it can be used with parametric tests more suitably.
- ❖ Chi-Squared test stands for mean and is used for fitting distribution to continuous data sets and it gives best results when the number of observation greater than 30. In this study, valid number of observed ballast capacity data is 184 for discharging ballast and 177 for loading ballast, therefore preferred in comparisons.

4.1.2.1 Analysis of discharging ballast quantity

The statistics of daily discharging ballast water is obtained by researching the raw data in the timescale. When discharging operation is considered for the period of 6 months (184 days), as in table 4.2, it is determined that the mean is 8341.98, medyan is 6326.45 and standard deviation is 7131.20.

When the analyzed data are compared to the raw data in table 4.2, it can be interpreted as; the standard deviation in both analyses is in similar levels. The mean of the analyzed data increased 2 times when compared with the mean of raw data, prove that the addition is done to datum as defined in section 4.1.2. The 75 % of the data is below the value 11418.32. This indicated that percentile of raw data is spread compared to the percentile of analyzed data. The decrease of skewness value from 2.72 to 1.61 explains that the distribution is becoming more fit. Thus, the data fits in to a particular distribution in the frame of these interpretations (Figure 4.4).

At this stage, the most suitable and valid distribution is researched for different confidence levels (99%, 98%, 95%, 90% ve 80%) by appliying the chi-squared test to 40 different statistical distribution for ballast discharge operation. In 80% confidence level, confidence interval level becomes narrower. So, if the hypothesis is not rejected that the distribution comes from a specific one, then it cannot be rejected for 80%, 90%, 95%, 98%, 99%. For this reason, the bigger the confidence level, the wider confidence interval is.

It is seen that, in several statistical distributions chi-squared test give suitable results with confidence interval by 80%. By using graphics, gamma distribution is selected as the most suitable distribution among these distributions and used in calculations (Figure 4.4).

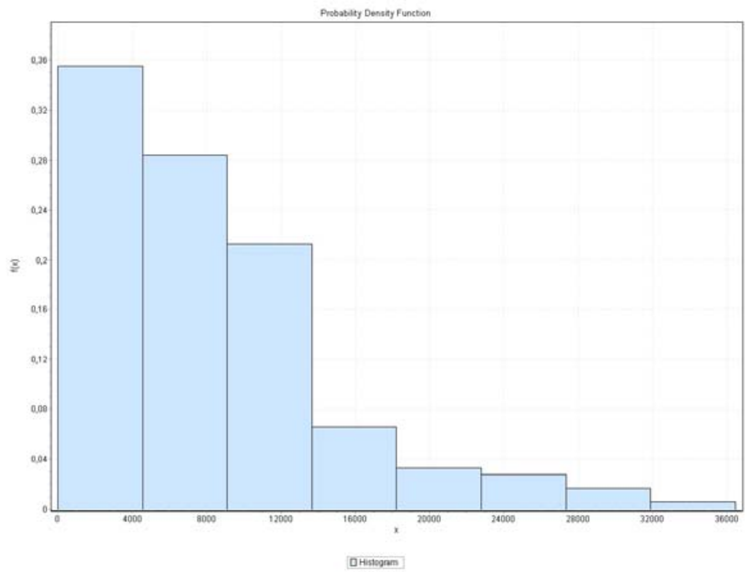


Figure 4.4 Probability density function of data of ballast discharging capacity

4.1.2.2 Analysis of loading ballast quantity

Considering the ballast loading operations between 4th of July in 2007 to 26th of December in 2007, the observation number is determined to be 177 days. When compared with table 4.2, the observation number of raw data -51- in timescale for the period of 6 months, the data raised up to 177 days by addition of non-operating days resulting from the analysis.

Addition of non-operating days to data set, the most repeated number (mode) found to be "0.00". It is determined that the mean is 4744.86 and standard deviation is 487.82. In comparison with the raw data mean, approximately ¼ decreases in the ratio is observed, this caused the raw data spreads in the timescale. This shows that the distribution becoming more fit. The skewness value changed from negative to positive. It means tail of the distribution towards right whereas it was towards left before. The most fitted and valid distribution is searched by applying the Chi-squared test to 40 different statistical distributions for ballast loading operation. As it can be interpreted from the figure 4.5, the distribution does not fit in a particular distribution.

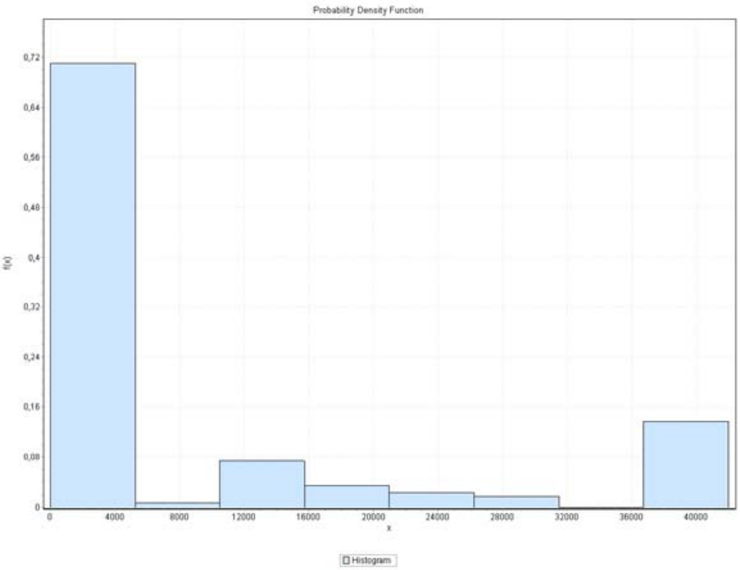


Figure 4.5 Probability density function of data of ballast discharging capacity

In the second step, it is observed that, the analysis do not develop in a proper direction when starting and ending time for the ballast operation for each incoming tanker is not taken into consideration. Thus the defined approach in the step 3 is applied.

4.1.3 Step 3: Transforming into Timely Basis

At this stage, the data are studied in timescale considering the amount of ballast water and its duration to the beginning and ending time of the ballast operation for each tanker.

The duration and the hours of the ballast operation of tankers are taken into consideration and the calculations done in step 2 are repeated. This time, "1st day, 2nd day, 3rd day and 4th day rates" are used instead of "left over ballast amount of 1st, 2nd, 3rd and 4th day" as terminology. Considering the rate of duration of the daily ballast operation time for each tanker's discharged/loaded ballast amount is determined. This way amount of daily total discharged/loaded is also determined (Annex V and Annex

VIII). Due to the processes done for discharging/loading operations being similar up to this point the series of actions are summarized as above.

4.1.3.1 Analysis of discharging ballast quantity and evaluations

As stated in paragraphs 2 and 3 in section 4.1.2, after the standardization of data is provided in metric system, the calculations are done considering each tanker's arrival and departure hours. That means, at this stage, hourly data is used only. So, during the operation time, the amount of daily discharge ballast water from tankers is found in ratio. The details related to calculations are shown in Annex V.

The ballast water amount for each tanker is calculated by finding out in what rate and during what days the discharge operation is done. That way, the amount of the daily total discharged ballast water is found as in the Annex VI.

During 184 days, the amount of discharged ballast water is analyzed for each day and found the mean as 8394.93, median as 6939.17 and standard deviation as 6542.094 (Table 4.2). Because of 75 % of the data below the value of 11153.39, it is found that 75% of the incoming tankers discharge ballast water under this value. When the percentiles compared it is determined that the analyzed data spread around more than raw data (figure 4.15).

13 distributions are found not rejected in the 80% confidence level when Chi-squared test is applied to 40 different statistic distributions.

The fitting 13 different statistical distribution's test results and distribution functions are in the table and figures below. (Table 4.3 to 4.15 and Figure 4.6 to 4.15).

Table 4.2 Statistics of raw, daily and timely data for ballast discharging and loading condition

Statistics		**Discharging Data**			**Loading Data**		
		Step 1 (Raw data)	**Step 2 (Daily data)**	**Step 3 (Timely data)**	**Step 1 (Raw data)**	**Step 2 (Daily data)**	**Step 3 (Timely data)**
# of Observation	Valid	365	184	184	51	177	178
	Missing	0	181	181	314	188	187
Mean		4231,97	8341,98	8394,93	16467,45	4744,86	7863,65
Std. Error of Mean		336,21	525,719	482,29	1064,99	487,82	737,63
Median		1894,67	6326,45	6939,17	16008,00	957,00	3704,00
Mode		2086	0	0	6426	0	0
Std. Deviation		6423,42	7131,20	6542,09	7605,53	6489,96	9841,22
Skewness		2,72	1,61	1,65	-0,20	1,27	1,28
Std. Error of Skewness		0,13	0,18	0,18	0,33	0,18	0,18
Kurtosis		7,58	2,51	3,25	-1,72	0,32	1,12
Std. Error of Kurtosis		0,26	0,36	0,36	0,66	0,36	0,36
Range		37325	34150	36447	19055	22547	48157
Minimum		274	0	0	6130	0	0
Maximum		37599	34150	36447	25185	22547	48157
Sum		1544668	1534925	1544668	839840	839841	1399730
Percentiles	25	1191,87	3351,75	3651,26	7182,00	0,00	0,00
	50	1894,67	6326,45	6939,17	16008,00	957,00	3704,00
	75	2392,60	11418,32	11153,39	23657,00	7800,50	12326,00

Table 4.3 “Goodnes of fit” details for Erlang [#5] distribution

Erlang [#5]					
Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	184 0,08532 0,12948 14				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	0,0791	0,09016	0,10011	0,11191	0,12009
Reject?	Yes	No	No	No	No
Anderson-Darling					
Sample Size Statistic Rank	184 5,4212 12				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	1,3749	1,9286	2,5018	3,2892	3,9074
Reject?	Yes	Yes	Yes	Yes	Yes
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 12,82 0,07661 11				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**Yes**	**Yes**	**No**	**No**	**No**

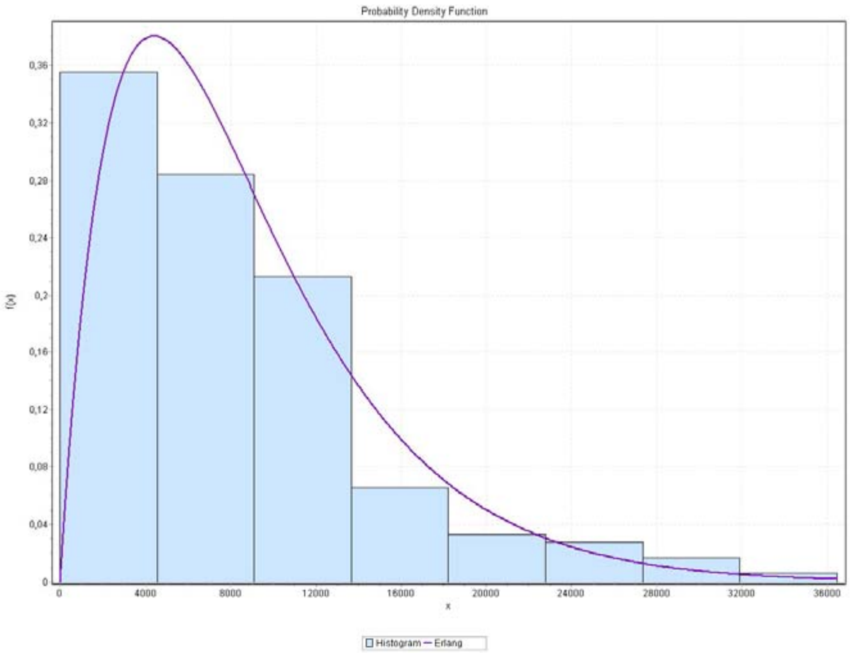


Figure 4.6 Probability density function of Erlang [#5] distribution

Table 4.4 “Goodnes of fit” details for Fatigue Life [#10] distribution

Fatigue Life [#10]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 6,0208 0,53732 6				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**No**	**No**	**No**	**No**	**No**

Table 4.5 “Goodnes of fit” details for Fatigue Life [#11] distribution

Fatigue Life [#11]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 6,0208 0,53732 5				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**No**	**No**	**No**	**No**	**No**

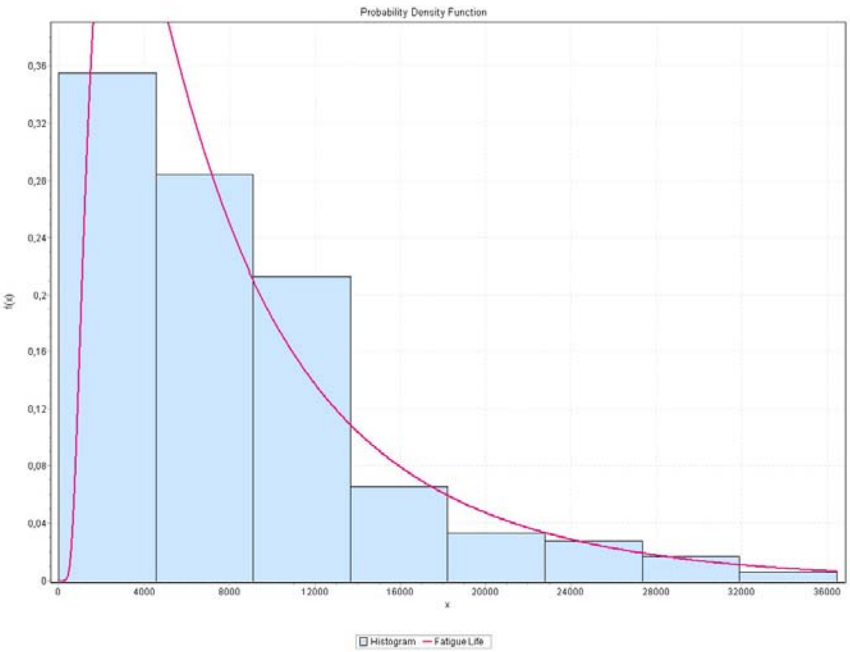


Figure 4.7 Probability density function of Fatigue Life [#10 & 11] distribution

Table 4.6 “Goodnes of fit” details for Gamma [#10] distribution

Gamma [#14]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 6,2459 0,51135 7				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**No**	**No**	**No**	**No**	**No**

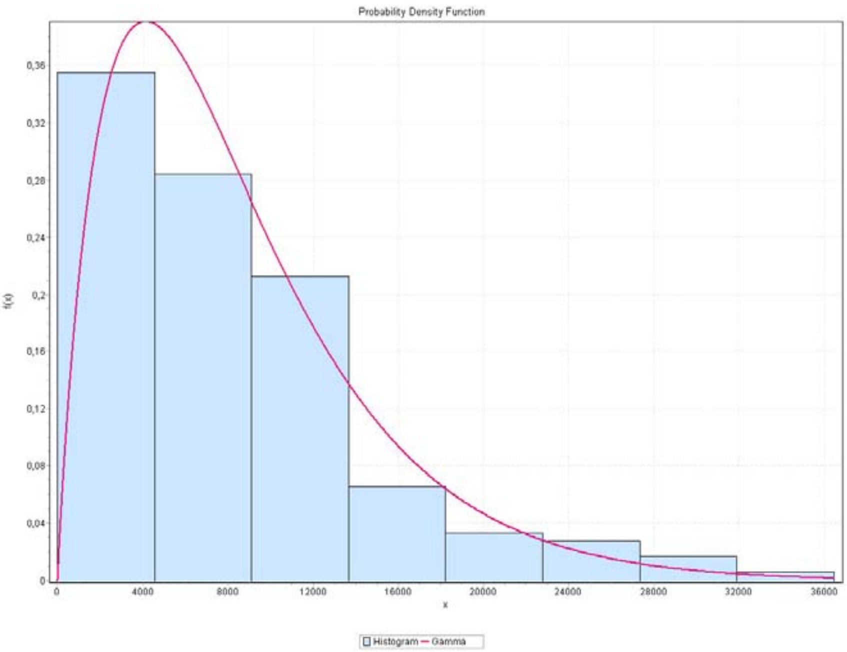


Figure 4.8 Probability density function of Gamma [#14] distribution

Table 4.7 “Goodnes of fit” details for Extreme Values [#16] distribution

Gen. Extreme Value [#16]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 5,9051 0,55087 4				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**No**	**No**	**No**	**No**	**No**

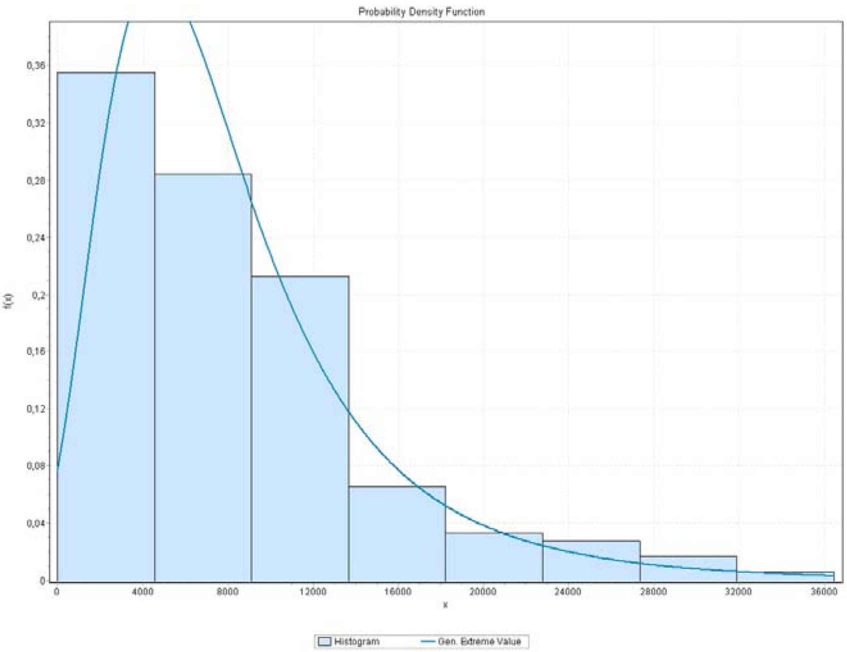


Figure 4.9 Probability density function of Gen. Extreme Value [#16] distribution

Table 4.8 "Goodnes of fit" details for Inv. Gaussian [#20] distribution

Inv. Gaussian [#20]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 6,4125 0,49249 8				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**No**	**No**	**No**	**No**	**No**

Table 4.9 "Goodnes of fit" details for Inv. Gaussian [#21] distribution

Inv. Gaussian [#21]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 10,128 0,18143 10				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**Yes**	**No**	**No**	**No**	**No**

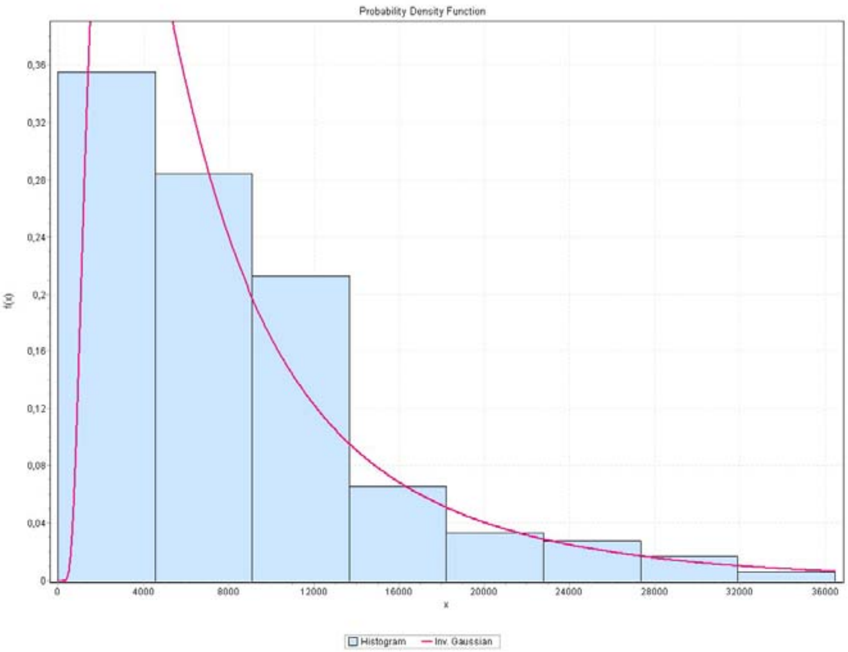


Figure 4.10 Probability density function of Inv. Gaussian [#20 & 21] distribution

Table 4.10 "Goodnes of fit" details for Lo-Logistic [#25] distribution

Log-Logistic [#25]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 6,9318 0,43601 9				
□	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**No**	**No**	**No**	**No**	**No**

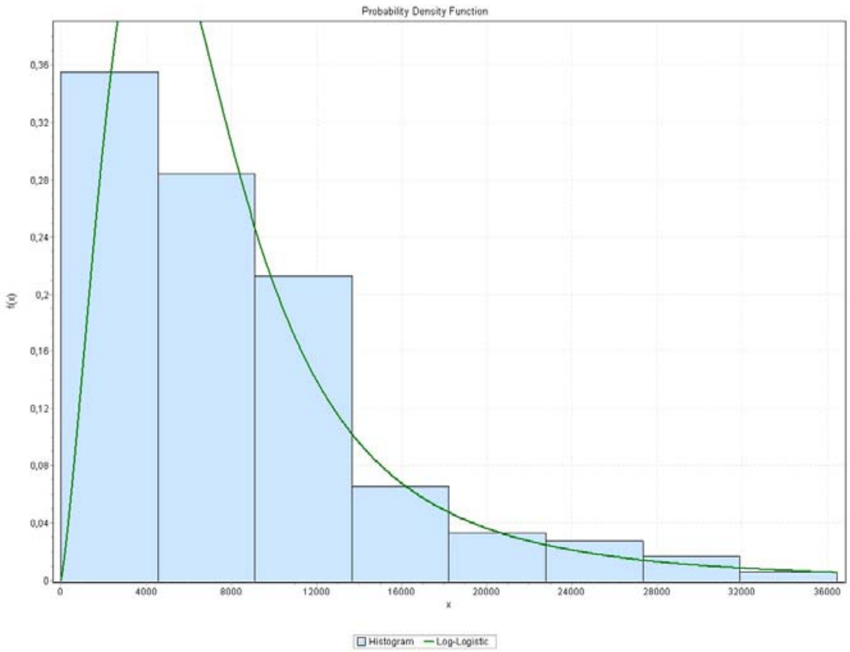


Figure 4.11 Probability density function of Log-Logistic [#25] distribution

Table 4.11 "Goodnes of fit" details for Lognormal [#27] distribution

Lognormal [#27]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 4,8798 0,67463 2				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**No**	**No**	**No**	**No**	**No**

Table 4.12 “Goodnes of fit” details for Lognormal [#28] distribution

Lognormal [#28]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 4,8798 0,67463 3				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**No**	**No**	**No**	**No**	**No**

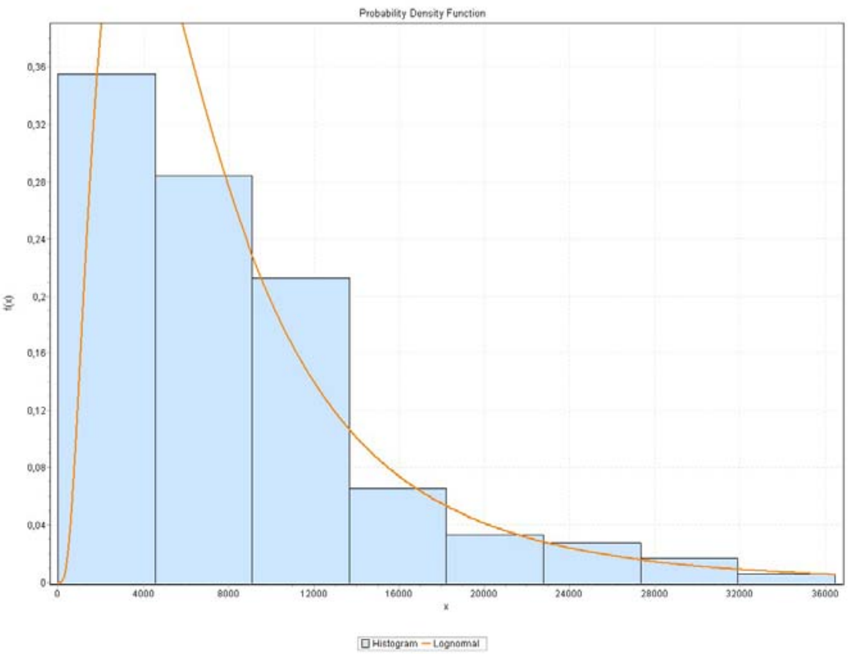


Figure 4.12 Probability density function of Lognormal [#27 & 28] distribution

Table 4.13 “Goodnes of fit” details for Pert [#30] distribution

Pert [#30]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 13,217 0,06699 12				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**Yes**	**Yes**	**No**	**No**	**No**

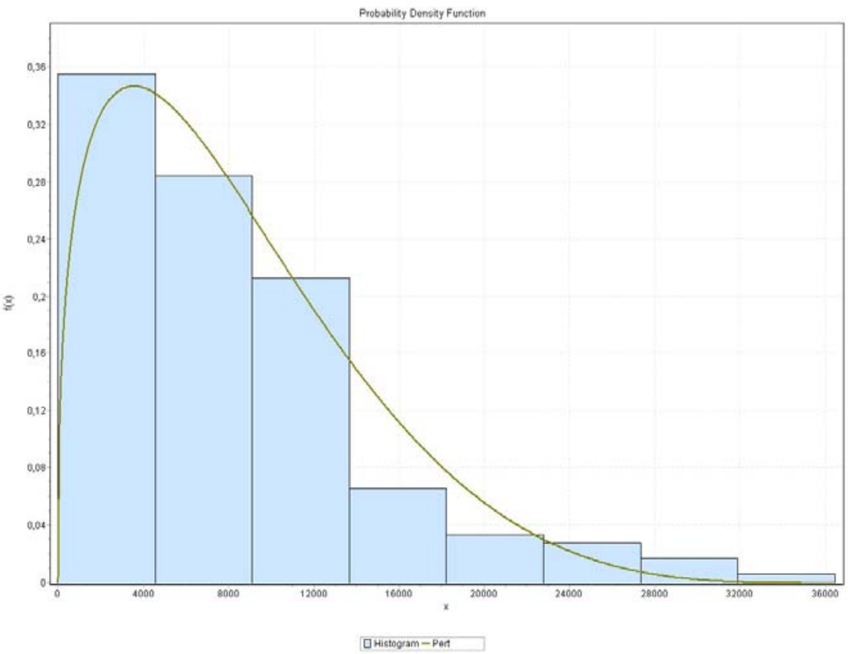


Figure 4.13 Probability density function of Pert [#30] distribution

Table 4.14 “Goodnes of fit” details for Weibull [#38] distribution

Weibull [#38]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 15,759 0,02741 13				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**Yes**	**Yes**	**Yes**	**No**	**No**

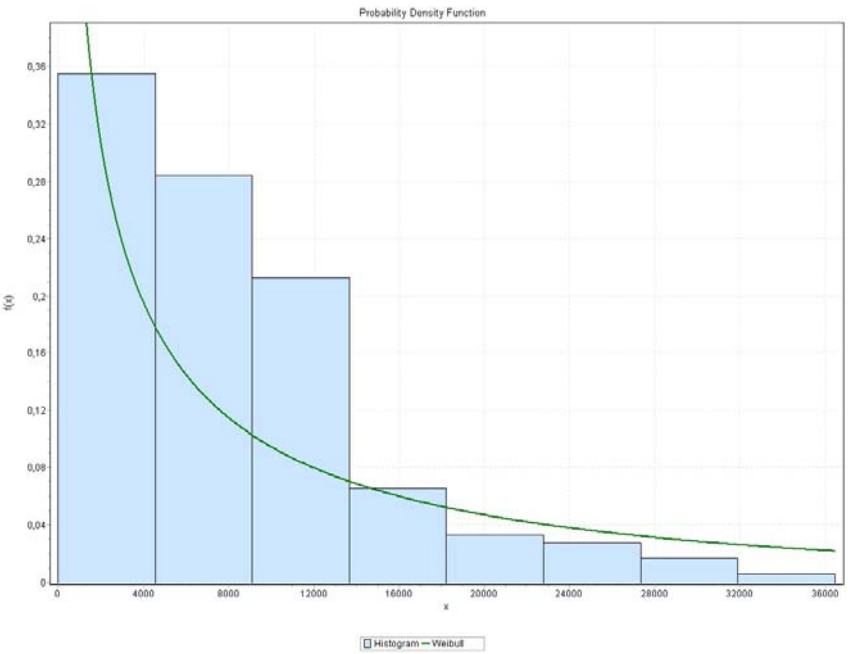


Figure 4.14 Probability density function of Weibull [#38] distribution

The calculations are done after studying the graphics and finding out that Gamma distribution (#15) is the most proper function to the distribution of daily total amount of discharged ballast.

Table 4.15 “Goodnes of fit” details for Gamma [#15] distribution

Gamma [#15]					
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	7 4,4643 0,72501 1				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	9,8032	12,017	14,067	16,622	18,475
Reject?	**No**	**No**	**No**	**No**	**No**

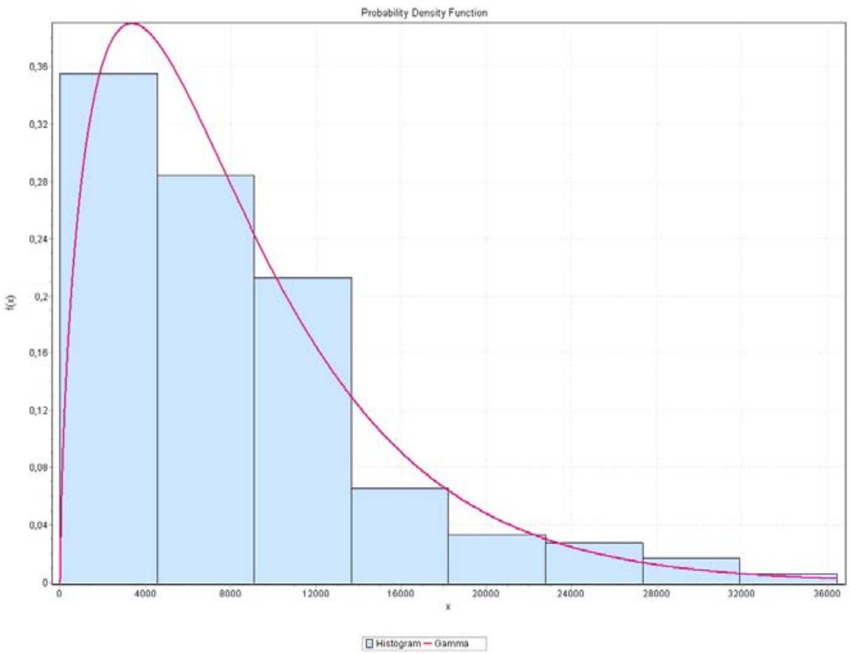


Figure 4.15 Probability density function of Gamma [#15] distribution

Gamma Distribution:

The gamma distribution is a two-parameter family of continuous probability distributions. The equation defining the probability density function of a gamma-distributed random variable x is

$$f(x;k,\theta) = x^{k-1}\frac{e^{-x/\theta}}{\theta^{k}\Gamma(k)} \quad \text{for} \quad x > 0 \quad \text{and} \quad k,\theta > 0$$

Alternatively, the gamma distribution can be parameterized in terms of a shape parameter $\alpha = k$ and an inverse scale parameter

$$g(x;\alpha,\beta) = \frac{\beta^{\alpha}}{\Gamma(\alpha)}x^{\alpha-1}e^{-\beta x} \qquad \beta = 1/\theta \quad \text{for} \quad x > 0$$

If α is a positive integer, then $\Gamma(\alpha) = (\alpha - 1)!$

Both parameterizations are common because either can be more convenient depending on the situation.

A future projection is made by using the parameters of Gamma distribution (#15) in Annex VII. To achieve this, 10 sets of 365 each annual random numbers are generated by using Easyfit Distribution Fitting Software.

Determination and Evaluation of the Capacity of Reception /Equalization Tank

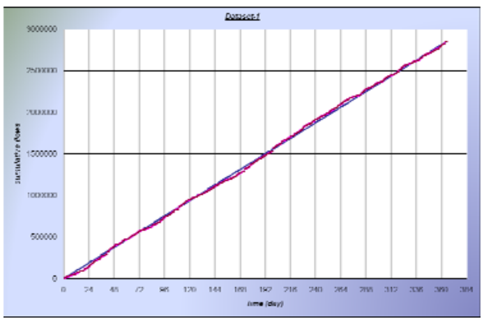
From this stage on, a reservoir capacity of storage tank is determined to generate 10 different data sets according to the Gamma distribution. For determining the capacity of a storage reservoir, mass curve (Rippl diagram) method which is the most widely used one shall be implemented.

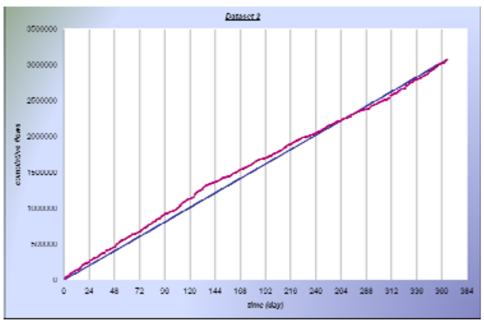
Once the critical period, the period during which inflow is less than demand, is selected by examining the past stream flows either natural or synthetically generated, storage requirements are calculated by evaluating the cumulative difference between inflow to the reservoir and the yield (Yanmaz, 2001, pg.12).

The values obtained by the calculations done for 10 different data sets by using mass curve (Rippl diagram) method are placed as summary in the table 4.16 and figure 4.16.

Table 4.16 Summary of 10 different datasets

	Total	Average	Total Differential	Maximum	Minimum
Dataset 1	2,853,232.24	7,817.07	73,509.85	20,832.91	-52,676.95
Dataset 2	3,075,765.65	8,426.76	255,501.00	180,343.14	-75,157.86
Dataset 3	3,283,150.77	8,994.93	121,989.51	84,268.76	-37,720.74
Dataset 4	3,181,520.62	8,716.49	110,674.48	41,999.11	-68,675.37
Dataset 5	2,880,047.25	7,890.54	100,914.47	60,179.38	-40,735.09
Dataset 6	2,842,389.95	7,787.37	158,615.51	114,248.95	-44,366.56
Dataset 7	2,750,491.59	7,535.59	85,863.64	Dataset repeated	
Dataset 8	2,992,648.73	8,199.04	108,399.43	65,548.98	-42,850.44
Dataset 9	3,227,798.87	8,843.28	106,685.02	98,309.94	-8,375.08
Dataset 10	3,076,824.03	8,429.65	131,979.58	100,160.15	-31,819.43





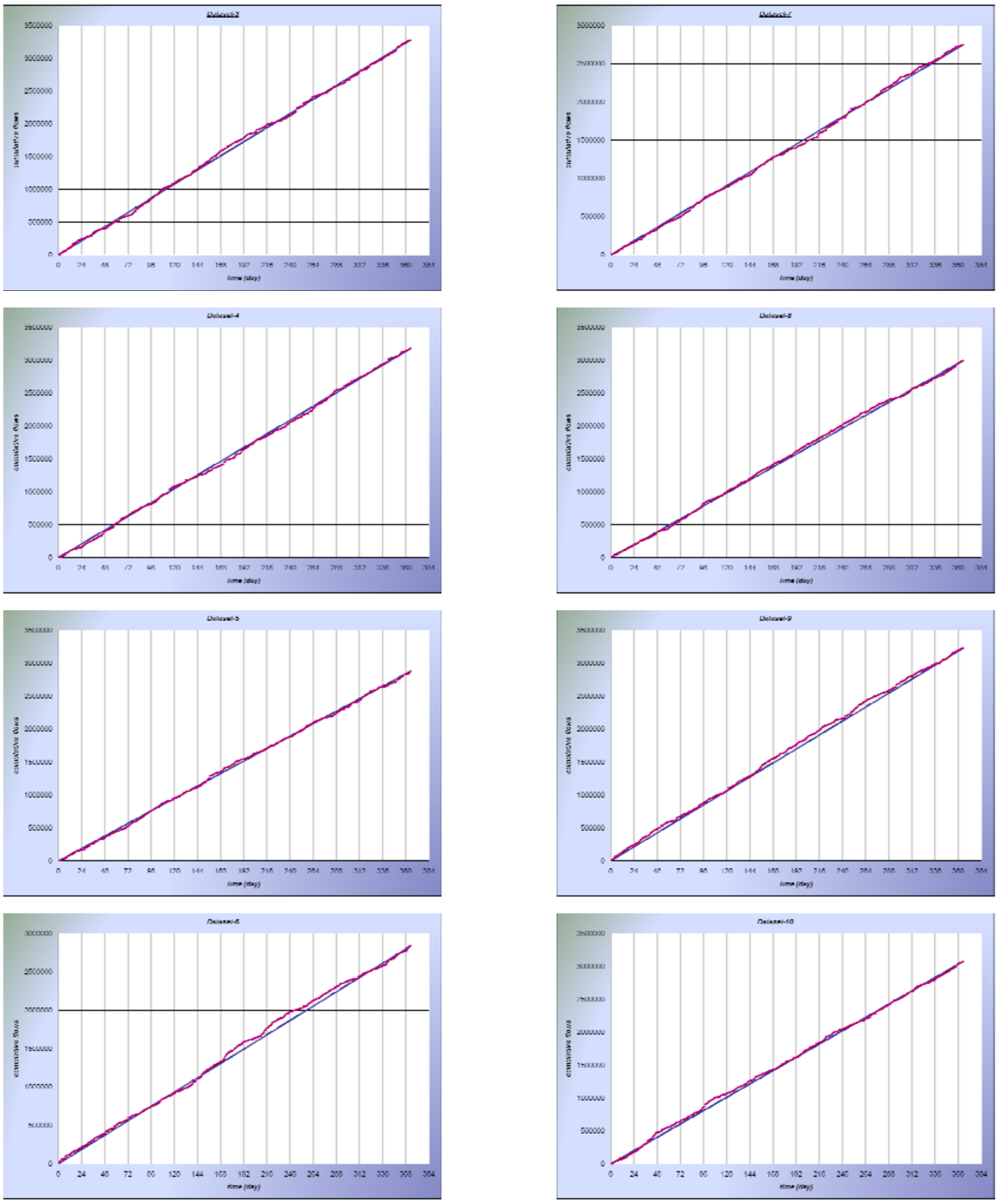


Figure 4.16 Rippl diagrams of 10 different datasets

The average reservoir capacity which was calculated for each data set is shown in figure 4.17.

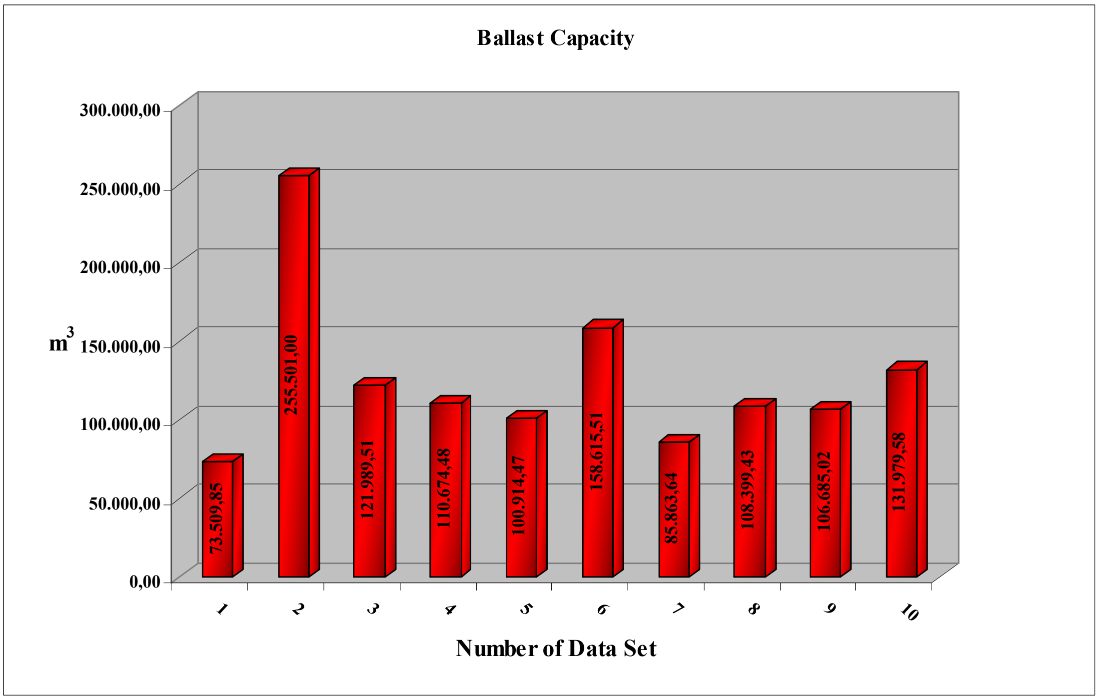


Figure 4.17 Reservoir capacities for 10 different datasets per year

Gamma distribution is a continious one and each of the data set is generated with the parameters of this distribution. The average value of these data sets determined as 125413,24 m^3/year. When the data set 2 which has extreme value is omitted then the average value decrease down to 99863,14 m^3/year. This means that the capacity can be set as ~**100000 m^3/year** (99863,14 m^3/year).

As mentioned in the previous chapters, the primary purpose of the dissertation is to establish reception and treatment facility to prevent discharging of the organisms via ballast water by tankers into territorial waters. For this purpose, designing the possible highest capacity reception and treatment unit capable of giving service to the majority of in coming tankers is essential.

4.1.3.2 Analysis of loading ballast quantity

A calculation system is applied to find the amount of ballast loading which is similar to the calculation systematic that was applied before in section 4.1.3.1. During the loading operation of each tanker, the amount of ballast water taken in daily is found rationally by considering its arrival and departure hours. The details of the calculations are shown in Annex VIII.

By applying Chi-squared test to 40 different statistic distribution, it is found out that with 95% confidence level it almost fit with one single distribution which is Johnson SB.

Johnson SB Distribution:

The equation defining the probability density function of a Johnson SB distributed random variable x is

$$f(x) = \frac{\delta}{\lambda\sqrt{2\pi}\,z(1-z)} \exp\left(-\frac{1}{2}\left(\gamma + \delta \ln\left(\frac{z}{1-z}\right)\right)^2\right) \quad \text{where} \quad z \equiv \frac{x-\xi}{\lambda}$$

$$\xi \leq x \leq \xi + \lambda$$

γ - shape parameter

δ - shape parameter ($\delta > 0$)

λ - scale parameter ($\lambda > 0$)

ξ - location parameter

Table 4.17 “Goodnes of fit” details for Johnson SB [#19] distribution

Johnson SB [#19]					
Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	178 0,22784 1,3916E-8 4				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	0,08042	0,09167	0,10179	0,11378	0,1221
Reject?	Yes	Yes	Yes	Yes	Yes
Anderson-Darling					
Sample Size Statistic Rank	178 8,6889 1				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	1,3749	1,9286	2,5018	3,2892	3,9074
Reject?	Yes	Yes	Yes	Yes	Yes
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	6 12,575 0,0503 1				
Confidence Level	0,2	0,1	0,05	0,02	0,01
Critical Value	8,5581	10,645	12,592	15,033	16,812
Reject?	Yes	Yes	No	No	No

By studying the data in the time scale during 178 days, tankers loaded ballast water data, is determined that, the mean is 7863.65, median is 3704.00 and standard deviation is 9841.22 (Table 4.2). The observation number’s being 178 instead of 177 which was indicated in step 2 is because the researches were done in hourly bases. The last day ballast operation’s transferring to the next day caused the observation number to become 178. As in figure 4.18, according to Chi-squared parametric test the distribution is fitted to Johnson SB distribution. The 75% of data is below the value 12326.00. So, when percentile compared to raw data percentile, the outcome is that data spreads around.

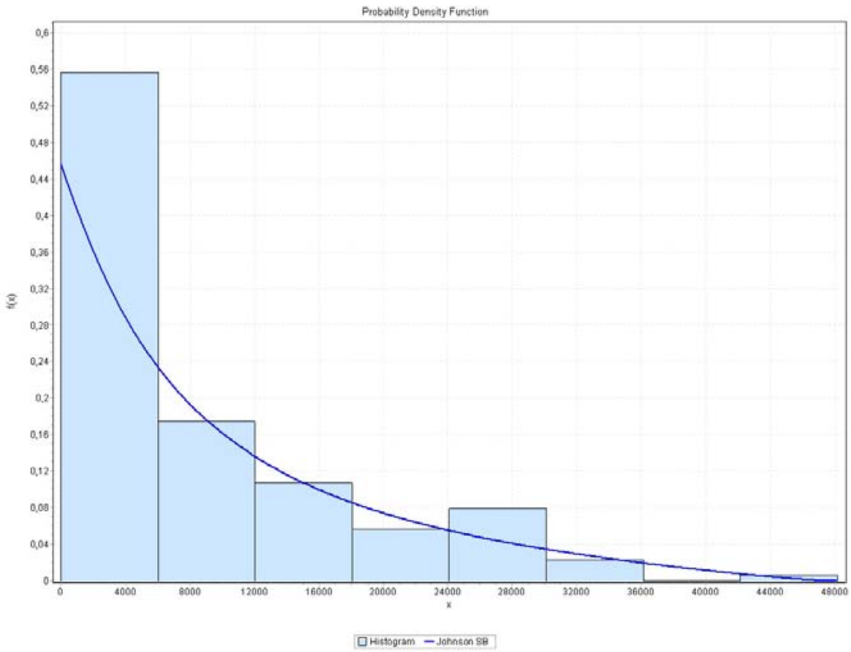


Figure 4.18 Probability density function of Johnson SB distribution

A future projection is made by using the parameters of Johnson SB in Annex IX. To achieve this, 10 sets of 365 each annual random numbers are generated by using Easyfit Distribution Fitting Software.

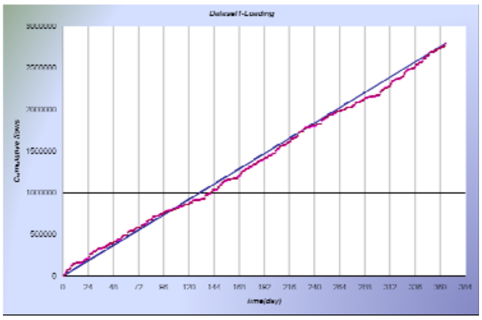
Some of the generated data resulted in negative values. Since ballast water values can not be negative, all the negative values are taken as 0.00 in calculations. Meaning that, it is considered as there was no ballast operation.

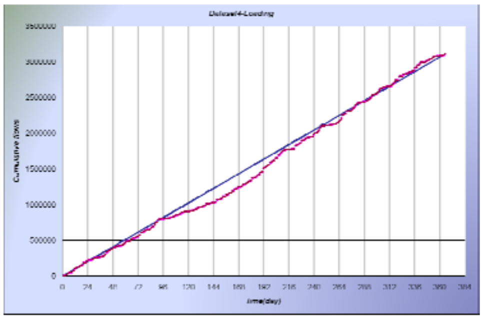
Determination and Evaluation of the Capacity of Storage Tank

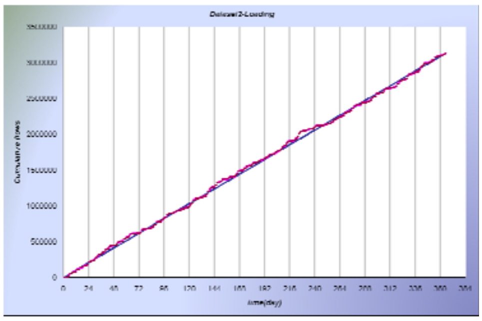
The values obtained by the calculations done for 10 different datasets by using mass curve (Rippl diagram) method are placed in the table 4.18 and figure 4.19.

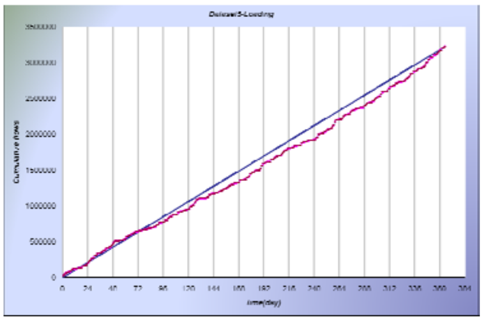
Table 4.18 Summary of 10 different datasets

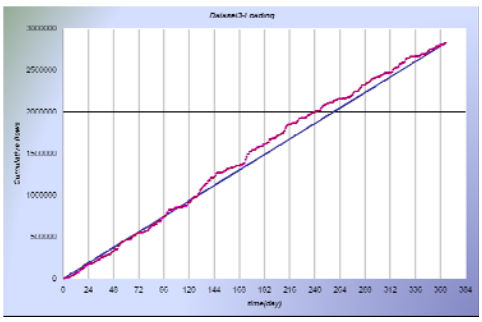
	Total	Average	Total Differential	Maximum	Minimum
Dataset 1	2,797,959.58	7,665.64	212,405.48	73,312.39	-139,093.09
Dataset 2	3,135,556.18	8,590.56	151,871.63	95,615.54	-56,256.09
Dataset 3	2,828,926.97	7,750.48	186,776.04	185,408.21	-1,367.83
Dataset 4	3,113,872.79	8,531.16	227,761.68	18,419.73	-209,341.95
Dataset 5	3,228,413.71	8,844.97	274,057.81	70,470.68	-203,587.13
Dataset 6	2,955,572.65	8,097.46	125,144.37	Dataset repeated	
Dataset 7	3,156,375.81	8,647.60	227,167.30	21,063.61	-206,103.69
Dataset 8	3,009,673.84	8,245.68	230,808.89	219,631.07	-11,177.82
Dataset 9	3,041,160.76	8,331.95	209,625.32	154,900.46	-54,724.86
Dataset 10	3,401,873.46	9,320.20	252,623.51	238,263.22	-14,360.29

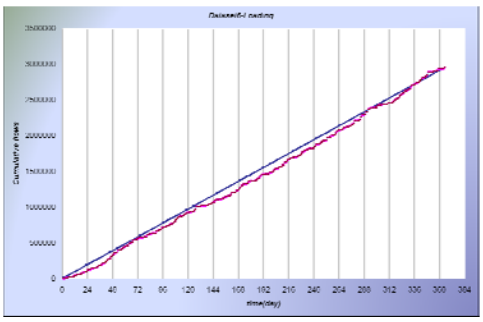












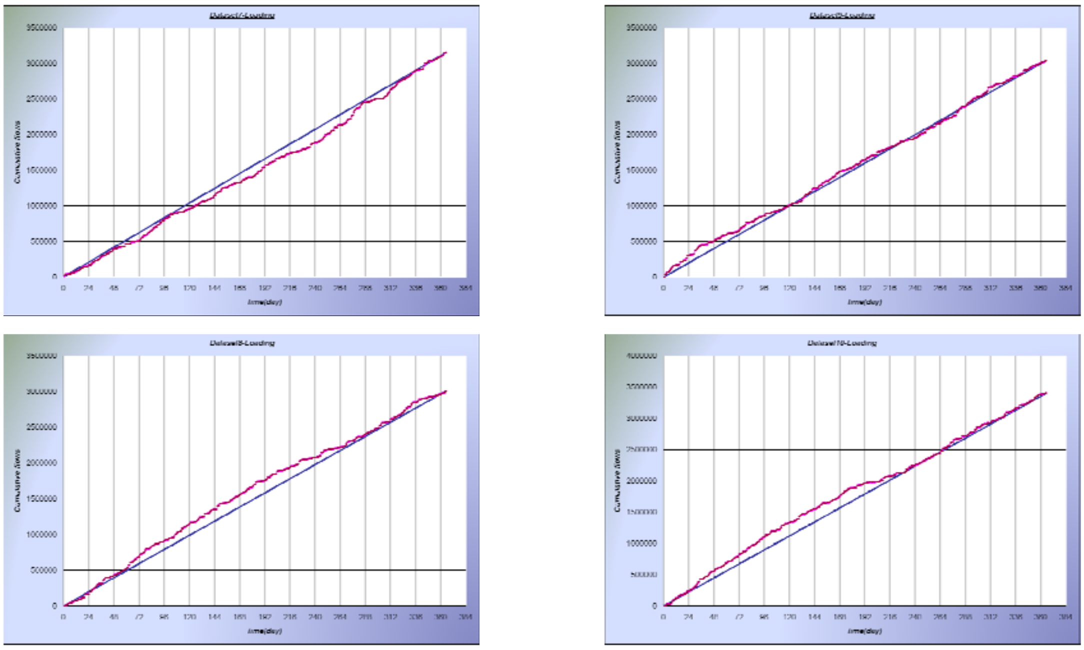


Figure 4.19 Rippl diagrams of 10 different datasets

The average reservoir capacity calculated for each data set is shown in figure 4.20.

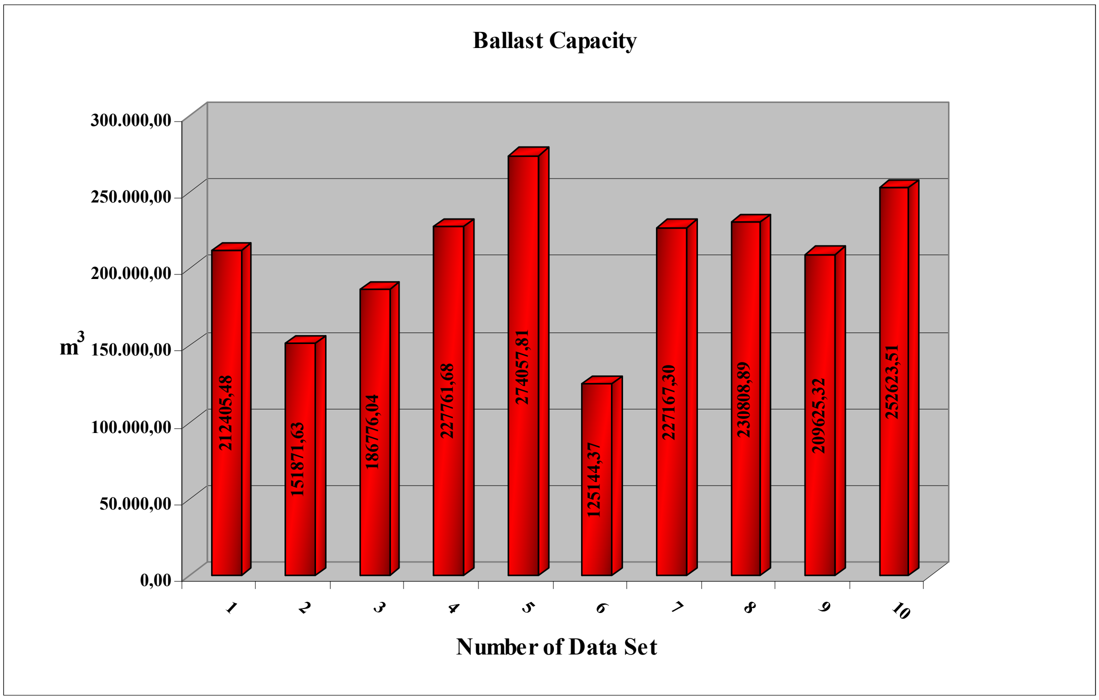


Figure 4.20 Reservoir capacities for 10 different datasets per year

The capacity of tank as a part of the facility planned to be build in the future, being capable of supplying high quality ballast water for the ships, is set as 209824,20 m^3/year (210000,00 m^3/year) when taken the average of the new data sets generated by using the parameters of Johnson SB distribution (Figure 4.20).

No research has been done in the number of the tankers requesting high quality ballast water in the frame of this dissertation. Rationally, the storage tank capacity must be equal to the capacity determined for reception/equalization tank. Because, the amount of input ballast water can not be expected to be smaller than the amount of output ballast water. So, it shall be suitable to set the storage tank capacity as approximately **100000 m^3/year.**

CHAPTER FIVE
BALLAST WATER MANAGEMENT SUGGESTIONS AND CONCLUSION

Varying commercial demands and supplies of countries build a connection between different geographic regions. Ships are the main vehicles that build these connections between geographies, which also continuously carry different types of organisms belonging to waters of different characteristics, from the regions they travel. Accordingly, ballast waters, carried by ships, change places between geographies, parallel to the demand/supply of the world trade. However, this cyclic movement causes the seas of the world and living organisms of different eco-systems to interfuse with each other more and more each day.

While the seas of the world and eco-systems in some geography are similar to each other, they are exteremely different in others. Management alternatives that are prepared by taking these similarities and differences into account will be the most successful alternatives.

By the statistical analysis of the gathered data, ballast water reception capacity of an on-shore ballast water reception and the treatment facility is designed to be 100000 m^3/year. To treat huge amount of seawater economically feasible, traditional treatment methods should be considered like equalization tank, screens, strainers, lamella settling tank, rapid sand filtration units and reception treatment tanks whereas concrete pools to be built instead of steel tanks. When considering the size and biodiversity of marine organisms, producing high quality ballast water/sea water which is specified in the convention as discharge standards, it will be possible by using one of the systems such as ultra filtration, chlorination, ozonation or ultraviolet units, namely solo or secondary treatment, in addition to the systems used in traditional treatment.

It should be taken into consideration several variables to design a treatment facility having such a capacity:

- *The amount of discharging ballast water*: Changes in the amount of the ballast water, due to the number of tankers which are discharging ballast water simultaneously.

- *Duration of the ballast water operation*: Changes in duration of the operation depends upon the amount of the ballast water to be discharged by the tankers.

- *Flow rates of the ballast water pumps*: Due to tankers having different flow rate ballast water pumps, the amount of the ballast water entering in to treatment facility being non-linear during simultaneously discharge of the tankers.

Due to the stated variables, filters to be used and treatment units which take place in the treatment system will be determined accurately. Therefore, in this section, the suggestions are given to enable alternative systems.

5.1. Design of an On-shore Balast Water Reception and Treatment Facility

The entry of the International Ballast Water Convention into force in the near future will play an effective role in preventing the seas and ecosystems, as long as the mandatory rules and recommendations are abided. On-shore treatment facilities which are only advised in the Convention for today are expected to be the main actors for this role in the future.

However, since it is not a mandatory instrument, some ambiguities (ballast water intake/discharge requests of the ships, ballast water amounts to be taken in/discharged and the frequency of the ballast discharge) will complicate the design of these facilities. Inevitably, it will take time to design and to equip, after solving this multiple variable equation in the optimum and economical way. Therefore, conducting comprehensive research on these facilities and presenting design alternatives is an important step for the future.

On-shore ballast water reception and treatment facilities are composed of main and sub units. The main parts are reception, treatment and storage units, whereas lines, pumps, non-return valves and etc. are the sub-units.

5.1.1 Reception Unit (Equalization/Reception Tank)

It is the entering point of the facility that the ballast water discharged from tankers either changeable or fixed flow rate-causes turbulence. It is possible to transfer the received water to the treatment unit in linear form. It is very important to provide fast service to ships, particularly in intensive ports (refinery ports, container terminals, etc.), in order not to hinder the trade. Because of this, ballast water operations should be completed in a pace that does not cause any delay. The role of the ship in the operation is to discharge the ballast water via the pumps of the ship, depending on the cargo loading conditions. The role of the port, on the other hand, is to take in the ballast water in accordance with the quarantine rules, without delaying the operations of the ship. Therefore, reception units should be established in the optimum capacity that minimizes the possible congestion and inconveniences in the port. This way, delays in the operation, caused by the port can be avoided. Reception units can come in various designs or alternatives. Some of those are presented below:

- Designing steel tanks within the port area,
- Using a single hull tanker (phased out), to avoid loss of space in the port,
- Designing a tank/pond outside of the port area in/under the ground

Each of the alternatives has advantages, as well as drawbacks. Table 5.1 shows these alternatives in comparison with each other.

Another interesting utilization alternative for the reception units is that they can provide ballast water to ships that discharge cargo, when requested. While it is unlikely to be preferred in normal conditions, use of this alternative is rational in one condition:

when reception facilities are available in ships' next port of call. In this case, ballast water will work as a "closed system circuit". The system will work efficiently, as long as there are no leakages or misapplications. Such an application is expected to offer a double advantage for the ship owners/operators. The operation will consequently be economic, since the ship will not use its own pumps during the ballast operation (shore facility pumps are used) and will take in untreated ballast water.

Another important point about reception units to be considered is the kind of management alternative that this unit will require in different occupancy ratios (Figure 5.1).

- ❖ Empty Unit: When the reception unit is empty, it is expected to serve ships that request ballast discharge, as much as its capacity allows. Particularly one point here is important. It is acceptable that the reception unit is empty at one instant. However, it is undesirable, if the unit is empty in general, due to design based on incorrect projections/calculations. Hence, it is important to determine the capacity of the reception unit and to design, for the efficient operation of the system.

- ❖ Partially Full Unit: When the reception unit is partially full, it is predicted that it can serve for ship/ships that have a ballast capacity that is equal to its available capacity. When requested, it can take in ballast water from ships that exceed its capacity, to the extent that it can handle. In this case, another management alternative has to be offered for the amount that cannot be handled, such as discharging in the city sewerage system.

- ❖ Full Unit: When the reception tank completely full during the ballast operations, it poses an unsolvable situation for ships requesting ballast discharge and an undesirable situation for port states. One of the two important points to be considered is to prevent the discharge of the ballast to the sea, and the other point is to avoid the delay of the ship when the port cannot fulfil the ballast operation request or slow down the operation in order to fulfil the request. If the ship is delayed even though loading is completed, because of the port's ballast operation, a fine may be imposed. In this case, the port should be imposed to pay demurrage per hour, for the time it caused the delay of the ship.

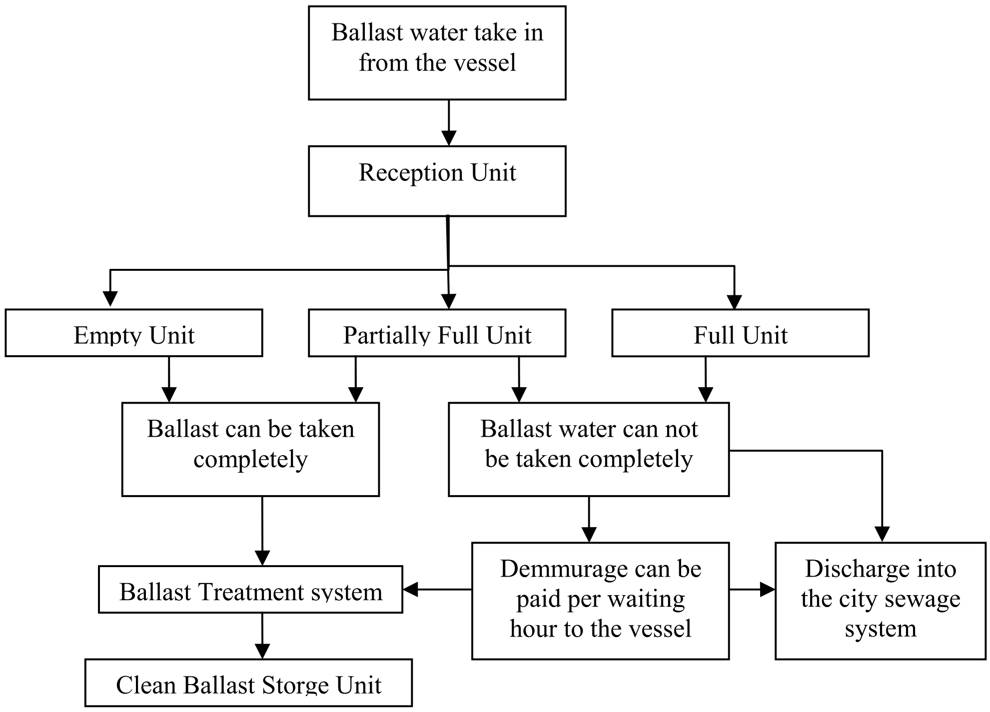


Figure 5.1 Management alternatives for different fullness ratios

Table 5.1 Alternatives for reception facilities and their advantages and drawbacks

	Within the Port Area		***Outside the Port Area***
	On-shore Treatment Facility	*Reception Barge*	*On-shore Treatment Facility*
Advantages	❖ Quick service ❖ Main pump unit not required ❖ Possibility to use fixed main fire line on the dock, as ballast reception line ❖ Useful for low ballast capacity ships (Ro-ro, ro-pax, container, cruise etc.)	❖ Low investment cost (a phased out tanker) ❖ Low cost due to flexible hoses	❖ Relatively low land cost ❖ Relatively low investment cost ❖ Saving the port land ❖ No limitation on storage ❖ Useful for high ballast capacity ships (tankers, bulk carriers etc.) ❖ Relatively low maintenance costs, due to the use of conventional treatment technologies
Drawbacks	❖ Expensive port land ❖ High investment cost ❖ Service limitations for high ballast capacity ships and high cost ❖ Limited storage and treatment possibility ❖ Extra maintenance cost ❖ Need for advanced and fast treatment technologies ❖ Need for trained staff ❖ Increase in cost due to steel tanks ❖ Lack of "standard ballast connection flange" on ships	❖ Risk of collision with berthing ships ❖ Damaged flexible hoses annihilate quarantine ❖ High maintenance cost ❖ Extra piping for connection to treatment system ❖ Lack of "standard ballast connection flange" on ships ❖ Need for trained staff	❖ Need for main and sub pumping units ❖ Need for extra pumping mechanism on slopped land ❖ Decrease in the flow rate due to losses ❖ Loss of time ❖ Extra energy consumption ❖ Need for sub storage unit ❖ Need for trained staff ❖ High cost of extra pipeline

5.1.2 Treatment Unit

This is the unit needed for the treatment of the ballast waters collected in the reception unit. Ballast water, complying with the standards is provided by the employment of one or more of the methods referred to in on-board treatment systems. The treatment unit must be designed and equipped in a way that does not allow any interruption in the system.

Screens/Strainers:

As defined in chapter II, there are living organisms in the ballast water ranging from bacteria to the largest protozoa. In addition to this, there are floating objects, sediments and some pollutant materials in the sea water taken in to the ship. In order to capture the large size living organisms and floating flocs after the equalization tank(s), the strainers with the screen and mesh size 100-250 μm are placed. This way all the fish, invertebrates, small juvenile forms and macrophytes kept out of the filter.

Chemical Dosage:

As used in the conventional drinking water treatment plants, in the settling unit, using additional chemicals, the suspended materials turns in to bigger particles which were suspended and colloid in the water by coagulation and flocculation methods. Settling will take place as a result of particles becoming bigger and getting heavier.

For coagulation, coagulating chemical and suspended solids will be gathered in suitable conditions. Because of giving efficient results, PACS (poly aluminum chloride hydroxide sulfate), Aluminium Sulphade (Al_2 SO_4), Polyelectrolyte (anionic, cationic and non-ionic) is considered.

Inorganic coagulations: Not produced synthetically by a technology produced by human being, natural materials dissolving in the water or created by combining together with specific reactions. Combining iron in the reaction with acid produces $FeCl_3$ can be given as an example.

PAC: It is a kind of coagulant with 1% solution which can easily dissolve in the water with pH ranging from 3.5 to 4.5. Because of corrosive characteristics in the form of liquid, it must be kept in the acid proof containers. In general, as a component material to coagulation it has an increasing effect during the waste water treatment process. It is declared by Burkut Su Tekniği Ltd.A.Ş. (2009) that when 5-10 ppm applied to the sample from a natural lake, sedimentation of the living organisms, clearing the water, more then 50% improvement in getting rid of suspended solids and turbidity, depending on the changing intensity helping in sedimentation of the formed flocs in a shorter time, is observed.

Polyelectrolytes: They are synthetically produced chemicals with long chain like structures. In general, 90% is in granule form. The ones in granule forms are made ready to be used via dissolving in water by 0.2%-0.5%. Because of being a difficult process a special polyelectrolyte system is required. The system is made of a mixer, special pump, and sometimes heaters. They are in cationic and anionic characters. They are rated as powerful, semi powerful and weak in their own class.

Settling Tank:

Particles in colloid forms by chemically dosing method are taken in to the lamella settling tank for sedimentation. After the process, sludge is transferred from the bottom to the sludge thickener tank and eliminated or burned after the sludge drying process. The water is directed to the sand filters for filtration.

Sand Filters:

The observation is that, water's filtering through the different layers of soil get cleaner then the surface water by the means of turbidity and suspended solids, for this reason water is filtered through the different layers of soil. Thus sand filters are preferred systems in drinking and usage water treatment technology.

Sand filters give a cleaner look to the water by capturing the possible sediment and turbidity. Sand filters are used for capturing the foreign materials like particles, sand, rust and algae which are the cause of turbidity in the water taken as a parameter of the main pollution.

The advantages of sand filters are explained by Avrasya Arıtma (2009) as listed below:

- Initial investment cost of the facility is low.
- Comparing to the conventional systems the space need is much smaller.
- Works without the need of the human intervention.
- The running cost and energy expenditure is low.
- With the low water usage in regeneration it cleans the filter beds. It doesn't require addition chemicals.
- Its units are corrosion resistant in every way.

Today, because of having a larger surface, the quartz minerals like anthracite and zeolite are being used in 5-6 layer filters.

Anthracite:

It is used to eliminate the insoluble items like sand, mud, sediment and particles. After itself, it provides protection for the treatment units from sediment. This way the water gains a sediment free, colorless and clear look. Filtration not only takes place with filtering, it also happens by adsorption effect. When designed and selected correctly, very effective and fine filtration can be done as sensitive as 10 micron.

The usage advantages of anthracite (Rotatek, 2009):

- ❖ Longer serving time
- ❖ Lower loss of pressure
- ❖ Back wash water saving
- ❖ Longer life duration

Zeolite:

Zeolites are capable of capturing several contaminants in the water systems in environmentally friendly ways by their filtration skills. One of the most important characteristics of zeolite minerals is to have crystal gaps in different rates thus they are able to absorb the environmentally harmful elements (anion and cation state) in the waste water.

Having a highly porous structure Zeolites capture particles to the size of 4 micron. Zeolites have negative ions which enable to absorb cations, some inorganic contaminants and undesired odors. Zeolites capture various metal cations high selectively which are separable from liquids by exchanging ions. Natural Zeolites enable capturing heavy metal cations (Pb, Cu, Cd, Zn, Co, Cr, Mn and Fe; Pb, Cu) in highly selective manners from drinking and waste waters.

The usage advantages of Zeolite (Wikipedia, 2009):

- ❖ The raise in the system capacity lowers the initial investment and running cost.
- ❖ Having better quality output water provides better protection for the receiving environment.
- ❖ The Running cost is lower due to using less chemical dosage for eliminating nutrients.

- ❖ Sludge characteristics raise the reusability possibilities of the mud.
- ❖ Mud removal cost gets lower.
- ❖ A drop down in the need of Polyelectrolytes required for draining water out of the sludge will bring lower chemical costs.

The sea water coming out of the filter with anthracite used in the upper layer, zeolite used in the mid layer and sand used in the bottom layer will reach to the desired quality after using one of the process applications like ultra filtration(UF), chlorinating, ozonation or ultraviolet(UV).

Solo/Secondary Treatment Alternatives

Ultra Filtration (UF):

After sand filtration processing, ultra filtration method can be applied for very small microbial organisms. The reason for the application of UF at this stage can be explained as if UF is to be applied, at the moment of the ballast water's entering to treatment system, it is essential for UF capacity to be very high. On the other hand, since the larger particles are not eliminated, a rapid clogging will happen which will cause a drop down in the efficiency. However, water being processed through the screen, strainers, settling tank, sand filters will drop the parameter values of the turbidity, suspended solids and total organic compounds etc. This way, both the elimination level of the living organisms in the water entering to UF processing will be higher and the replacement of membrane and running costs will be lower.

Burkut Su Tekniği Ltd. Sti' (2009) explains the advantages of UF as listed below:

- ❖ Capable of filtering the water down to the level of 0.02 micron.
- ❖ UF system is a complete system which contains the full automatic back washing and chemical disinfection group.

- UF units are resistant to low and high pH chemicals and water having 200 ppm chlorine, for this reason, the disinfection of the UF can be done very successfully.
- The running cost is low due to filtration's being done under 3 bar pressure.
- When the UF system is back washing itself discharges only 3%-5% of its water flow rate.
- UF units are durable; they are not to be replaced frequently like filter cartridges.
- UF systems occupy very small space.

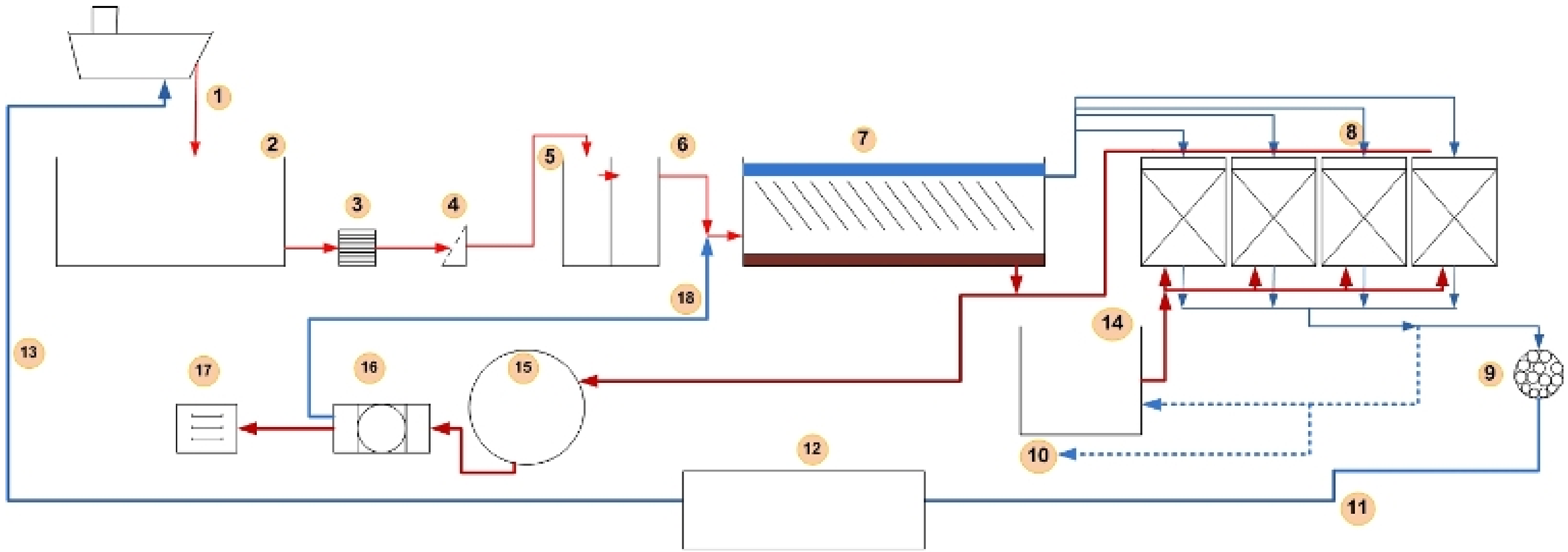
In figure 5.2, a system suggestion is placed for treatment by ultra filtration method.

Chlorination:

After the sand filtration, the sea water's microbiological disinfection is provided by application of chlorine as the advantages and drawbacks (table 3.17) are placed in chapter 3. It is a preferred system because of having low costs. On the other hand, the remaining chlorine in the output water will also kill living organisms existing in the ballast tanks of the ships requesting high quality ballast water. In figure 5.3, a system suggestion is placed for treatment by chlorination method.

Ozonation:

After the sand filtration, application of ozone will enable to kill microscopic organisms in the sea water as the advantages and drawbacks (table 3.18) are placed in chapter 3. It is preferred due to the non chemical byproducts and side effects. In figure 5.4 a system suggestion is placed for treatment by ozonation method.



1. BALLAST WATER INTAKE
2. BALLAST WATER EQUALIZATION TANK
3. STRAINER
4. SCREEN FILTRATION
5. INORGANIC COAGULANT DOSAGE
6. POLYELECTROLYTE DOSAGE
7. LAMELLA SETTLING
8. RAPID SAND FILTERS
9. ULTRAFILTRATION
10. FILTRATED WATER
11. ULTRAFILTRATED WATER
12. TREATED BALLAST WATER STORAGE TANK
13. TREATED BALLAST WATER SERVICE
14. BACKWASH WATER STORAGE TANK
15. SLUDGE COLLECTOR
16. FILTER PRESS
17. SLUDGE BURNER OR SLUDGE DRIER
18. WATER RECYCLE

Figure 5.2 Suggested treatment facility using ultra filtration method

Ultraviolet (UV):

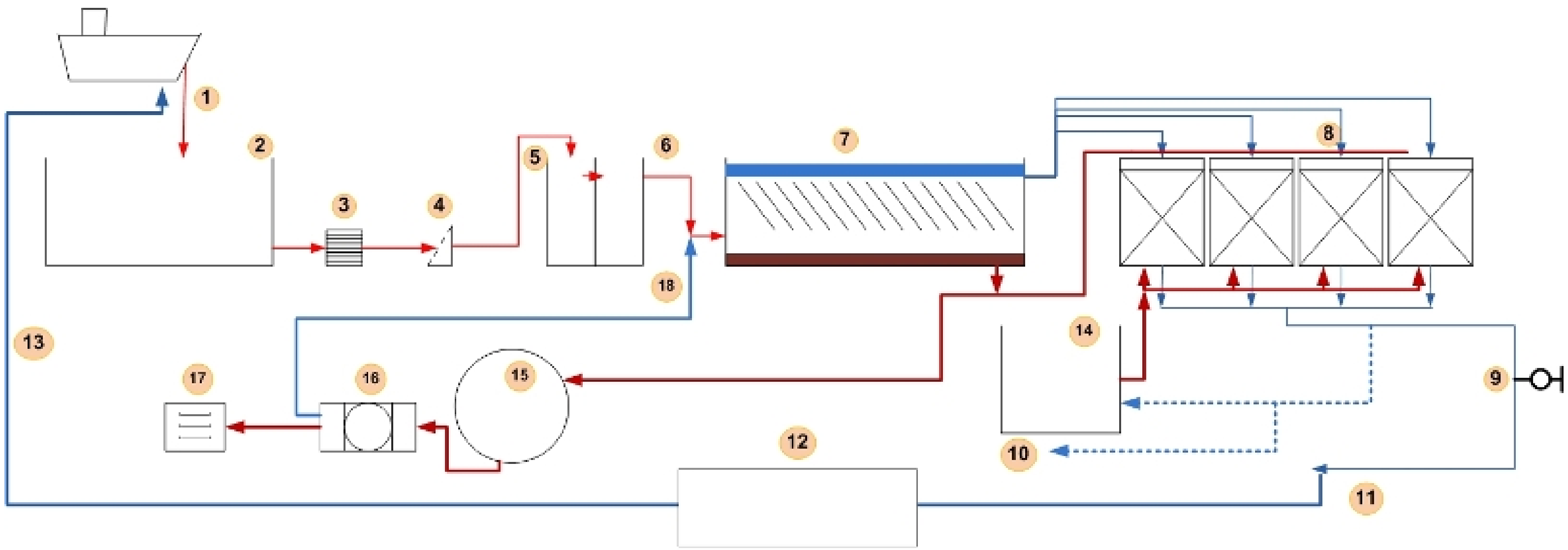
After the sand filtration, application of ultraviolet system will enable to kill microscopic organisms in the sea water as the advantages and drawbacks (table 3.10) are placed in chapter 3. Due to non toxic byproducts or residuals, it is environmentally friendly and no adverse effects on physical characteristics of the sea water, it will be a preferred method. In figure 5.5, a system suggestion is placed for treatment by ultraviolet method.

Since the treated ballast water becomes “high quality sea water”, it can be used in a wider range. To determine the usage of this high quality sea water and to provide management alternatives will increase the economical value of the water. Therefore, it would be good if the treatment unit includes secondary treatment adaptation units within the scope of clean water management alternatives to be offered.

The operation of the treatment unit depends on the reception unit. Treatment system will operate as long as there is water in the reception system. However, different management alternatives must be offered, in order to prevent the disabling of the system when the reception unit is empty. When the treatment unit is idle, an alternative is to take seawater from the shore and to feed it to the storage unit after treatment. In this case, also, the mechanical components of the system will work periodically, which will provide for the efficient operation of the treatment unit.

5.1.3 Storage Unit

It can be defined as the storage place of the ballast water in quarantine conditions, after it passes through the treatment system and the living organisms are eliminated. The storage tank capacities of the ships requesting high quality ballast water is determine as **100000 m^3/year.**



1 BALLAST WATER INTAKE
2 BALLAST WATER EQUALIZATION TANK
3 STRAINER
4 SCREEN FILTRATION
5 INORGANIC COAGULANT DOSAGE
6 POLYELECTROLYTE DOSAGE
7 LAMELLA SETTLING
8 RAPID SAND FILTERS
9 GAS CHLORINE DOSAGE
10 FILTRATED WATER
11 DISINFECTED WATER
12 TREATED BALLAST WATER STORAGE TANK
13 TREATED BALLAST WATER SERVICE
14 BACKWASH WATER STORAGE TANK
15 SLUDGE COLLECTOR
16 FILTER PRESS
17 SLUDGE BURNER OR SLUDGE DRIER
18 WATER RECYCLE

Figure 5.3 Suggested treatment facility using cholorination method

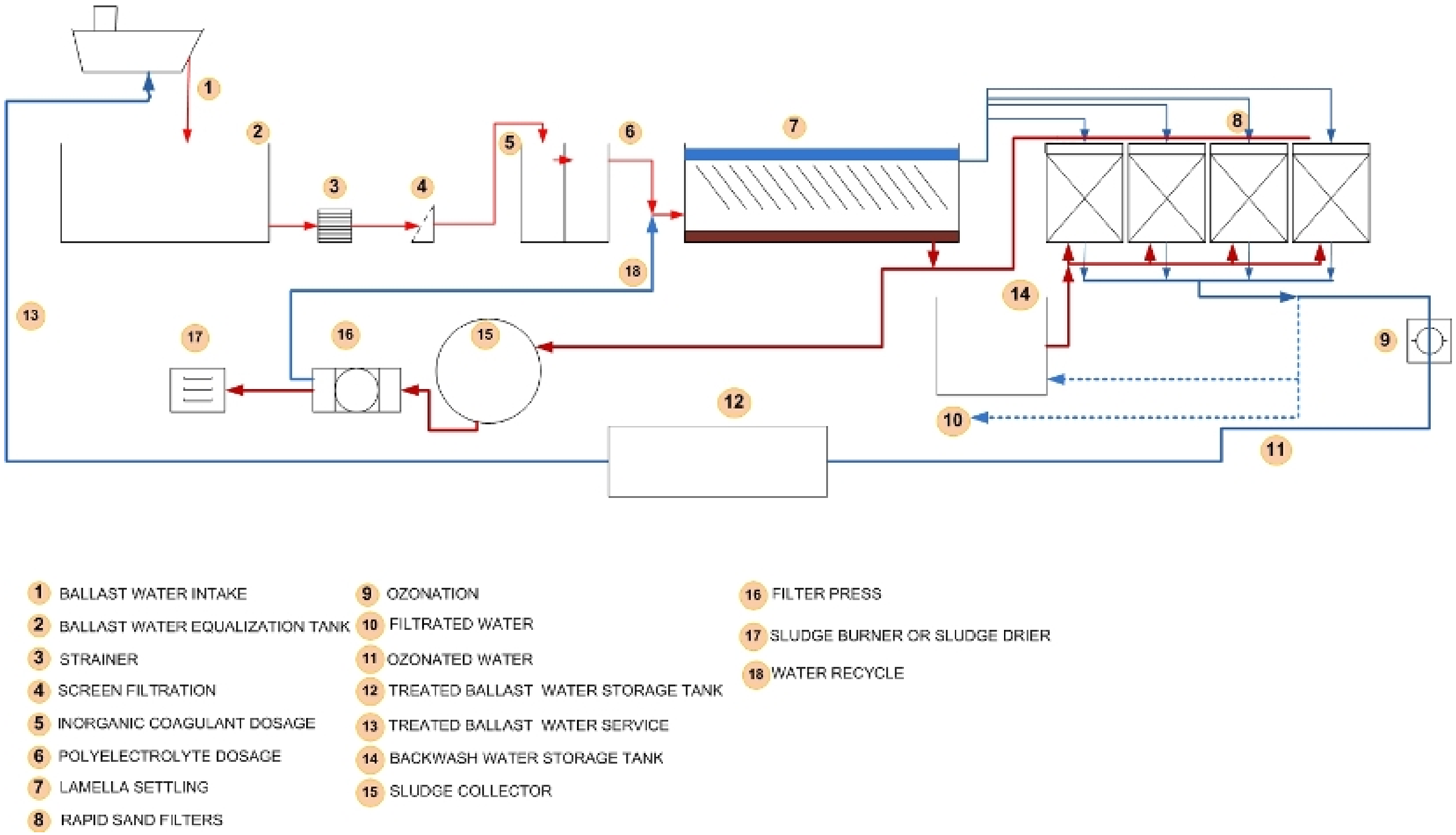


Figure 5.4 Suggested treatment facility using ozonation method

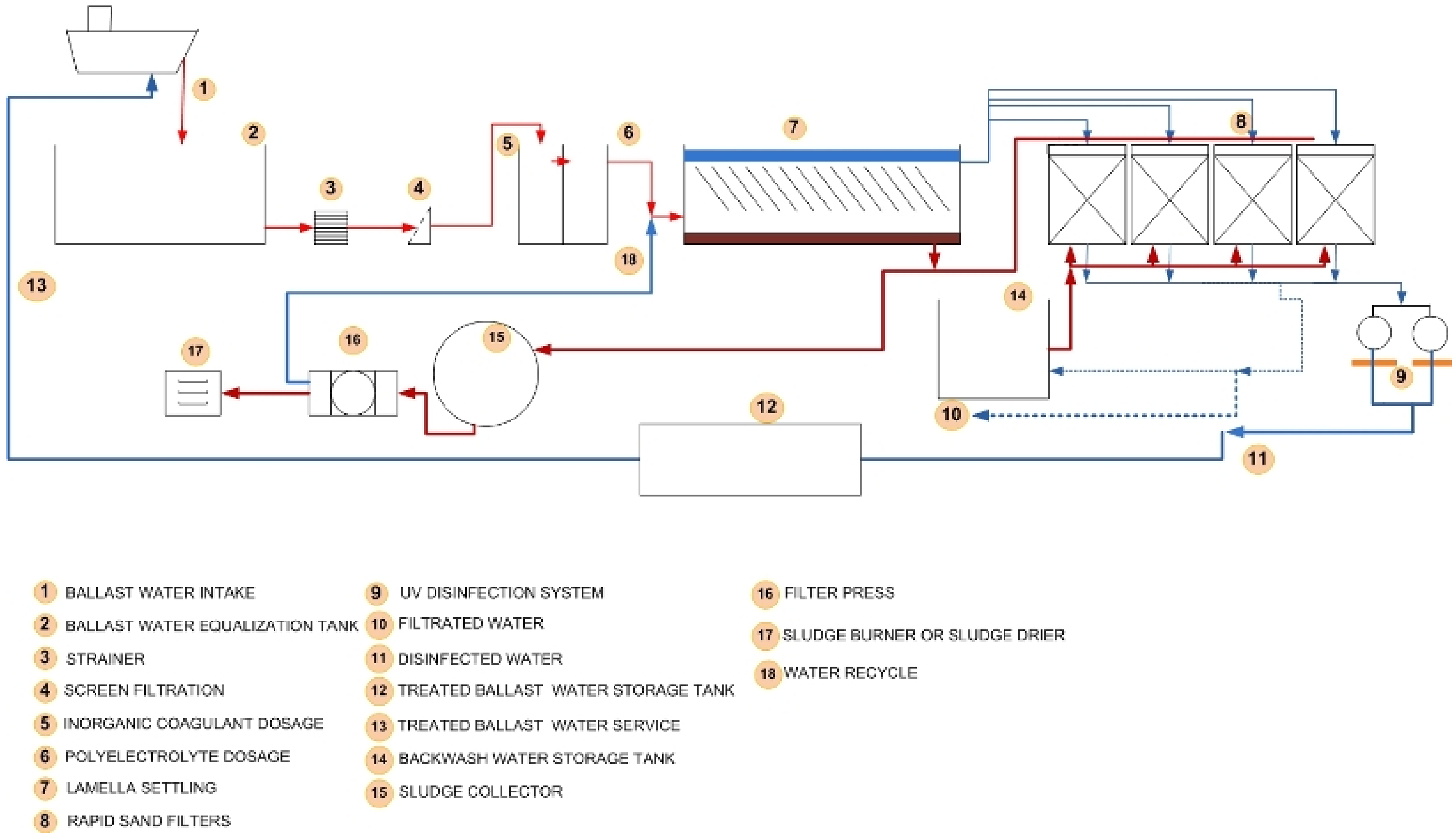


Figure 5.5 Suggested treatment facility using ultra violet method

5.2 Management Alternatives for High Quality Ballast Water

It is inevitable that ballast water operations that generated no extra cost until now will be now costly, due to the requirements of the Convention. It is clear that ballast exchange and treatment methods are costly methods, such as the exchange of volumetric capacity of the ballast tank 3 times, investment and operational costs of on-board systems installed on ship, etc.

The situation will be different for on-shore treatment systems. Since the reception facilities, referred to in the Convention are only advised for today, it imposes no sanctions for the states. However, it is predicted that states will establish these facilities, in order to protect their own territorial waters/EEZ's. Consequently, this shows that different implementations may come up, during the establishment of states' own national legislations. However, no matter what the implementations will be, charges will surely be reflected to ships, to amortize the operational costs of these facilities.

Since the ballast water, eliminated from living organisms will now have an "economical value", it will be possible to use this high quality ballast water (sea water) for different purposes.

5.2.1 Servicing to the tankers

As explained in chapter 4, the purpose of achieving high quality ballast water is primarily to supply ballast water to tankers when they discharge their cargoes. However, unpredictable intensity in the number of tankers which will request high quality ballast water, the capacity determined for the storage tank is estimated in this dissertation. The storage unit's being idle will be prevented by using sea water during the times of not giving service to tankers. Thus a different suggestion is proposed in section 5.2.2.

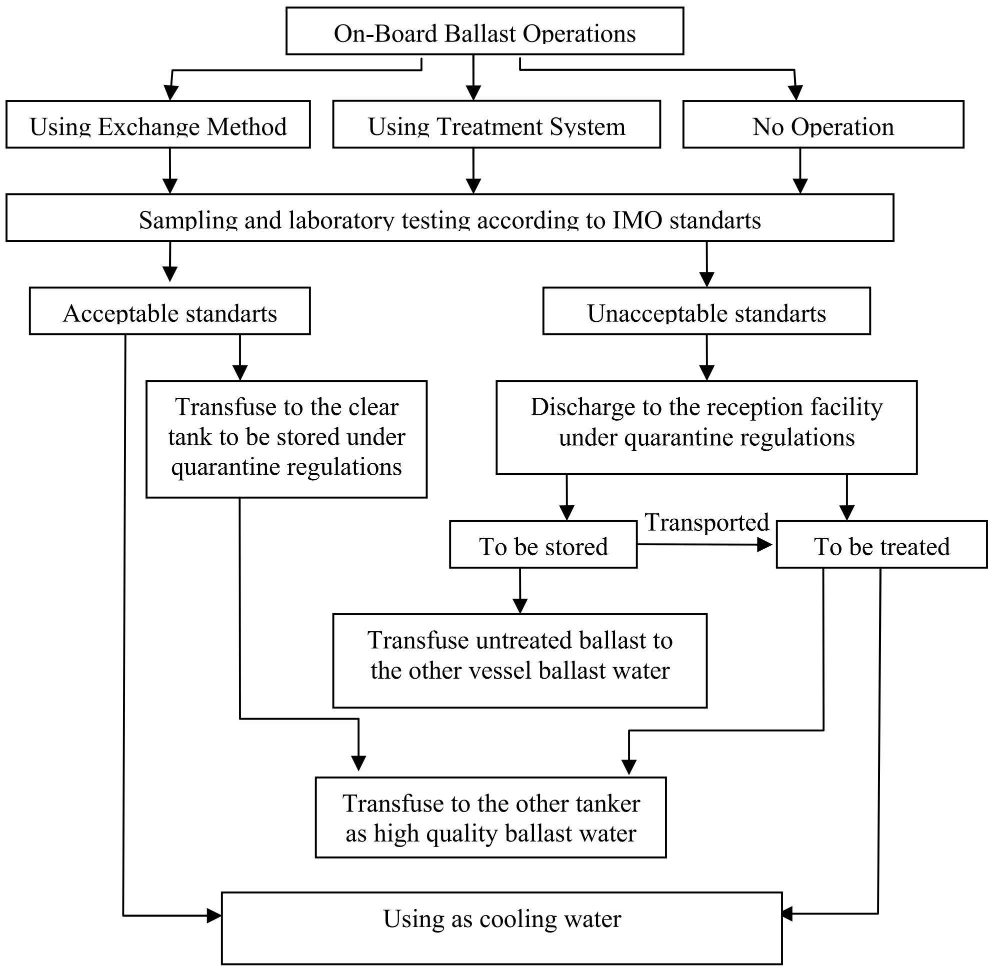


Figure 5.6 Management alternatives

5.2.2 Servicing to the industrial facilities as cooling water

Izmir, Aliaga region is a rapidly developing industrial area where the refinery port is selected as study area. As stated in the beginning of chapter 4, there are 2 refineries, several iron and steel industrial facilities in different capacities, several port facilities, energy plant and related industries. On 21 June 2008, the news in web page of “Ege Ekonomisi” said that Enka group, investing in construction and energy sectors, took action to build thermic power plant, in near future which will be in the capacity of 800 MW using imported coal in Aliaga where there is a natural gas power plant. In addition to this, as is mentioned in the news on web page of “Seaport Haber “on 28 June 2009, Aliaga Nemrut bay will be the centre of sea transportation by constructing 5 new ports where there are 9 ports in operation already.

At the same time, there is geothermal energy which is a renewable source of energy whose impact on environment is less harmful in comparison with other energy sources in the area. Currently, the geological investigations carried out in Aliaga shows that Aliaga region has a number of hot water springs and attracts attention of new prospects.

In the area, iron and steel factories, rolling plants and energy plants need good quality water to be used for cooling. The present energy plant supplies its need of cooling water via pipelines from the sea, even though being located away from the sea. The other industries use underground waters. According to the Ankara University research fund project final report (2001), the region may have valuable resources for the geothermal energy production and thermal temperature’s reaching up to 42^{o}C in certain areas, thus it doesn’t give very promising results in supplying the need of cooling water for iron-steel and other factories. The supply of cooling water for the industries shall support the potential needs.

This way, ballast water with no economical value is treated and brought in the economical cycle, as referred in the beginning of the chapter.

5.3 Conclusion

Varying commercial demands/supplies of countries build a connection between different geographic regions. Ships are the main vehicles that build these connections between geographies, which also continuously carry different types of organisms belonging to waters of different characteristics, from the regions they travel. However, this cyclic movement causes the seas of the world and living organisms of different ecosystems to interfuse with each other more and more each day. “International

Convention for the Control and Management of Ship's Ballast Water and Sediments", which was adopted in 2004 by International Maritime Organization is an important step towards the control of the ballast water transfers. The Convention refers to guidelines, as well as the mandatory requirements. Mandatory requirements includes ballast water exchange methods and on-board ballast water treatment. Careful and attentive practice of exchange method is necessary, in order to maintain on-board treatment system as an alternative until 2016. Each of the ballast treatment alternatives eliminate different living organisms with different methods. In short, no system is perfect stand-alone. One of the guidelines of the Convention is about the "Ballast Water Reception Facilities" and is only advisory for the time being. Following the entry of the Convention into force, some defects and failures may occur in mandatory practices. It is believed that these adversities can be eliminated by inspection and management from one single point, i.e. by way of establishing reception facilities in the ports. In the research, it is determined that besides having many advantages, on-shore facilities also have drawbacks which should be taken into account and eliminated. Some ambiguities will complicate the design of these facilities. Inevitably, it will take time to design and to equip, after solving this multiple variable equation in the optimum and economical way. Therefore, conducting comprehensive research on these facilities and presenting design alternatives is an important step for the future.

In order for the on-shore treatment facility to serve for all vessels coming to the port with full-capacity ballast, the treatment facility should be designed in infinite size. However, a treatment facility in infinite size is not expected to be economically feasible. The thesis introduces a projection of a treatment facility design, by using the data obtained from a refinery port and determining the estimated amount of ballast operations in that port. Two different statistical programs are used in the analysis as SPSS (Statistical Package for the Social Sciences) and Easy Fit Distribution Fitting Software Version 5.0.

The data are studied in timescale considering the amount of ballast water and its duration to the beginning and ending time of the ballast operation for each tanker. The ballast water amount for each tanker is calculated by finding out in what rate and during what days the discharging/loading operation is done. That way, the amount of the daily total discharged/loaded ballast water is found. Total amount of daily ballast which is suitable for a continuous distribution is determined by checking with Chi-Squared parametric test. The calculations are done after studying the graphics and finding out that Gamma distribution is the most proper function to the distribution of daily total amount of discharged ballast and Johnson SB distribution is for loaded ballast. A future projection is made by using the parameters of those distributions. To achieve this, 10 sets of 365 each annual random numbers are generated by using Easyfit Distribution Fitting Software. A reservoir capacity of reception and storage tanks are determined to generate 10 different data sets according to distributions and mass curve (Rippl diagram) method which is the most widely used shall determined approximately **100.000 m^3/year.** Rationally, the storage tank capacity must be equal to the capacity determined for reception/equalization tank. Because, the amount of input ballast water can not be expected to be smaller than the amount of output ballast water. The research done in this context show that the storage tank capacity which is determined approximately **100.000 m^3/year** is equal to the capacity of reception/equalization tank.

Since the reception facilities, referred to in the Convention are only advised for the time being, it imposes no sanctions for the states. However, it is predicted that states will establish these facilities, in order to protect their own territorial waters/EEZ’s. Consequently, this shows that different implementations may come up, during the establishment of states’ own national legislations. However, no matter what the implementations will be, charges will surely be reflected to ships, to amortize the operational costs of these facilities. Several management alternatives shall be suggested for using the facility efficiently. One of the utilization alternatives is unlikely to be preferred in normal condition, loading tankers with raw ballast water which is discharged for treating from another tanker. Use of this alternative is rational in one condition: when reception facilities are available in ships' next port of call. In this case, ballast water will work as a "closed circuit system". The system will work efficiently, as long as there are no leakages or misapplications. Such an application is expected to offer a double advantage for the ship owners/operators. The operation will consequently be economic, since the ship will not use its own pumps during the ballast operation (shore facility pumps are used) and will take in untreated ballast water.

In the study area, there are 2 refineries, several iron and steel industrial facilities in different capacities, several port facilities, energy plant and related industries. At the same time, there is geothermal energy which is a renewable source of energy whose impact on environment is less harmful in comparison with other energy sources. In the area, iron and steel factories, rolling plants and energy plants need good quality water to be used for cooling. The present energy plant supplies its need of cooling water via pipelines from the sea, even though being located away from the sea. The supply of cooling water for the industries shall support the potential needs.

On-shore reception and treatment facility which shall be established near industrial areas, 2-way-benefit as stated above shall be obtained. For this reason, future projections on the industrial areas shall carry great importance.

References

ABS American Bureau of Shipping. (1999). *Advisory notes on ballast water exchange procedures*. Retrieved December 24, 2006 from http://www.eagle.org/absdownloads/ listdetails.cfm?id=317.

Akın, T. (2000). *Gemi Stabilitesi*. İstanbul: Akademi Yayınları.

Ambrogi, A. O. (2001). Transfer of marine organisms: a challenge to the conservation of coastal biocoenoses. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 2001(11), 243–251.

Ankara University (AU). (May, 2001). *Araştırma Projesi Fonu Kesin Raporu Aliağa Jeotermal Sahasının Manyetotellürik Yöntem ile Araştırılması.* Retrieved July 06, 2009 from http://80.251.38.220/download/arastirma/ jeotermal001_aliaga.pdf

AQIS Australian Quarantine and Inspection Service. (March, 2008). *Australian Ballast Water Requirements*. Retrieved April 6, 2008 from http://www.daffa.gov.au/__data/assets/pdf_file/0004/713884/bw-requirements.pdf.

Avrasya Arıtma. (June, 2009). *Kum filtresi ile arıtma*. Retrieved June 23, 2009 from http://www.aritmaciyiz.com/index.php?option=com_content&task=view&id=21&Itemid=49

Beer, T. (1983). *Environmental oceanography. An introduction to the behaviour of coastal waters.* New York: Pergamon Pres.

Belgrano, A., Batten, S.D., Reid, P.C. (2001). Pelagic Ecosystem. *Encyclopedia of Biodiversity*. Academic Press. (4), 497-508.

BIMCO The Baltic and International Maritime Council. (November 3, 2003). *Ship stability explained*. Retrieved November 24, 2006 from http://www.bimco.dk/Corporate%20Area/Seascapes/Maritime%20Matters/Ship%20stability%20explained.aspx.

Buchholz, K., Tanis, D., Macomber, S. & Farris, E. (August 24, 1998). *Ballast water secondary treatment technology review*. Retrieved May 18, 2007 from http://www.nemw.org/Balsurv_Cover_Summary.htm.

Buck, E. H. (March 10, 2005). *CRS Report for Congress ~ Ballast water management to combat invasive species.* Retrieved January 4, 2007 from http://www.house.gov/ english/pdf/ballastwater.pdf.

Burkut Su Tekniği Ltd. Şti. (2009). *Ultra filtrasyon (UF) sistemlerinin uygulama alanları.* Retrieved May 4, 2009 from http://www.burkut.com.tr/urunler/ product1_3.html

Carlton, J. T. (1985). Transoceanic and interoceanic dispersal of marine coastal organisms: The biology of ballast water. *Oceanography and Marine Biology Annual Review*, 23, 313-71.

CBD Convention on Biological Diversity. (August 9, 2005). *Jakarta mandate marine and coastal biodiversity - invasive alien species*. Retrieved April 9, 2007, from http://www.biodiv.org/programmes/areas/marine/alien.aspx.

CETS Commission on Engineering and Technical Systems. (1996). *Stemming the tide ~ Controlling introductions of nonindigenous species by ships' ballast water*. Retrieved November 24, 2006, from http://www.nap.edu/books/0309055377/html.

Chu, K. H., Tam, P. F., Fung, C. H., & Chen, Q. C. (1997). A biological survey of ballast water in container ships entering Hong Kong. *Hydrobiologia,* 352, 201-206.

Cohen, A. N. (1997). *Proc. California and World Ocean'97 Conf. ~ The exotic species threat to California's coastal resources.* Retrieved December 16, 2006 from http://www.sfei.org/bioinvasions/Reports/1998-ExoticSpeciesThreat386.pdf.

Cohen, A. N. (1998). *San Francisco Estuary Institute ~ Ships' ballast water and the introduction of exotic organisms into the San Francisco Estuary: Current status of the problem and options for management.* Retrieved February 8, 2007 from http://www.sfei.org/bioinvasions/Reports/1998-BallastWater224.pdf.

Cohen, A. N., & Carlton, J. T. (1998). Accelerating invasion rate in a highly invaded estuary. *Science*, 279, 555–558.

Cohen, A. N., & Foster, B. (2000). The regulation of biological pollution: Preventing exotic species invasions from ballast water discharged into California coastal waters. *Golden Gate University Law Review*. 30(4), 787-883

DNV Det Norske Veritas. (2005). *Ballast water scoping study: North Western Europe*. Retrieved February 4, 2007 from http://www.seas-at-risk.org /1mages/North%20Sea%20BWM%20Scoping%20Study %20(1-2).pdf

DNV. (2007). *Ballast Water Management*. Retrieved January 16, 2007 from http://www.dnv.com/maritime/maritimeconsulting/technicalsolutions/ballastwatermng

Dobbs, F. C., & Rogerson, A. (2005). Ridding ships' ballast water of microorganisms. Is it even possible to remove, kill or "inactive" all of them-and if so, should we try? *Environmental Science & Technology*. 39(12), 259-264.

Doblin, M., Reid, D., Dobbs, F., Donahue, D., Fahnenstiel, G., Jenkins, P., Johengen, T., MacIsaac, H., and Ruiz, G. (2001). *Assessment of transoceanic NOBOB (No Ballast On Board) vessels and low salinity ballast water as vectors for non-indigenous species introductions to the great lakes*. Retrieved April 23, 2006 from http://www.sgnis.org/publicat/2mb_34.htm

Ege Ekonomisi. (21 Haziran 2008). *Aliağa'ya enerji santralı.* Retrieved July 4, 2009 from http://www.egeekonomisi.com/haber_detay.php?hid=12492

Evonik Ind. (n.d.). *Ballast water treatment with Peraclean® Ocean*. Retrieved January 11, 2007 from http://www.hyprox.net/content/ballast_water_treatment.htm

Foreship. (2005). *M/T "Palva" Double hull conversion*. Retrieved February 21, 2008 from http://www.foreship.com/references/ref-05.html

Gibson, G. (October 21, 2008). Personel contact via e-mail. IMO, London.

GL Germanischer Lloyd. (2006). *Leaflet for ballast water management*. [Brochure]. Retrieved January 18, 2007 from http://www.gl-group.com/pdf/ Leaflet_for_BWM.pdf

Glosten-Herbert, Hyde Marine. (April, 2002). *Full-Scale Design Studies of Ballast Water Treatment Systems.* Retrieved June 7, 2007 fro http://www.nemw.org/ full_scale_design_study.pdf

Gollasch, S. (November 19, 2002). *Ballast water management in the North-East Atlantic: Report to aid decision making on ballast water in OSPAR BDC*. Retrieved January 5, 2007 from http://www.gollaschconsulting.de/download/ BWM_OSPAR_BDC.pdf

Gollasch, S., David, M., Voigt, M., Dragsund, E., Hewitt, C. & Fuyuko, Y. (2006). Critical review of the IMO international convention on the management of ships' ballast water and sediments. *Science Direct. Harmful Algae.* 2007 (6), 585-600. Retrieved October 07, 2007, from Elsevier database.

Grassle, J.F. (2001). Marine Ecosystems. *Encyclopedia of Biodiversity*. San Diego: Academic Press. (4), 13-25

Günday, M. (February 4, 2008). Personel interview. Pilot Captain, Aliağa.

Hillman S., Hoedt F., Schneider P. (June, 2004). *Final report for the Australian Government Department of the Environment and Heritage- The Australian pilot project for the treatment of ships' ballast water.* Retrieved May 18, 2006 from http://www.environment.gov.au/coasts/pollution/antifouling/ballast/pubs/ballast.pdf

H & K (Holland & Knight). (2008). *Ballast water management technologies*. Retrieved December 1, 2008 from http://www.hklaw.com/content/maritime/mardocs/ BWM_Technologies.pdf

Hyde Marine Inc. (September 27, 2006). *Great Lakes Ballast Water Conference ~ Two ballast water treatment technologies*. Retrieved July 15, 2007 from http://www.greatlakes-seaway.com/en/pdf/Two_BWT_Technologies.pdf

IMO (International Maritime Organization). (November 27, 1997). *Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens. Resolution A.868(20)*. Assembly 20th session.

IMO. (August 25, 1999). *Focus on IMO ~ Alien invaders-putting a stop to the ballast water hitch-hikers*. IMO News Number 4.

IMO. (2002). *Oil Pollution*. Retrieved November 11, 2007 from http://www.imo.org/ Environment/mainframe.asp?topic_id=231#1

IMO. (2004). *The problem*. Retrieved October 4, 2006 from http://globallast.imo.org/ index.asp?page=problem.htm&menu=true.

IMO. (February 13, 2004). *International convention for the control and management of ships' ballast water and sediments*. Retrieved April 12, 2006 from http://www.imo.org/Conventions/mainframe.asp?topic_id=867

IMO. (2005a). *Ballast water convention gains first signatories.* Retrieved December 20, 2007 from http://www.imo.org/Safety/mainframe.asp?topic_id=1018& doc_id=4656

IMO. (2005b). Guidelines for ballast water exchange (G6). Resolution MEPC.124(53). Retrieved February 4, 2007 from http://www.mpa.gov.sg/ circulars_and_notices/pdfs/sc07-03b.pdf

IMO (2006). *MARPOL 73/78 - International Convention for the Prevention of Pollution from Ships*. (Consolidated ed.). London: IMO Publication.

IMO. (October 13, 2006). Guidelines for Ballast Water Reception Facilities (G5). MEPC 55/23. Annex 5.

INTERTANKO International Association of Independent Tanker Owners. (April 29, 2002). *Ballast water and invasive species*. Retrieved November 2, 2006, from http://www.intertanko.com/tankerfacts/environmental/ballast/ballast.htm.

INTERTANKO (2004). *Annual Review ~ The state of the industry 2004*. Retrieved November 11, 2007 from http://www.intertanko.com/about/annualreports/2004/ 1_2.html

ITOPF The International Tanker Owners Pollution Federation Limited. (2007). *Case Histories.* Retrieved December 28, 2007 from http://www.itopf.com/information-services/data-and-statistics/case-histories/

Kazumi, J. (2007). *Ballast water treatment technologies and their application for vessels entering the Great Lakes via the St. Lawrence Seaway*. Retrieved October 07, 2007 from http://onlinepubs.trb.org/onlinepubs/sr/sr291_kazumi.pdf

Kennish, M. J. (2001*). Practial handbook of marine science*. (3rd ed.). New Jersey: CRC Press.

Krebs, C. J. (2001). *Ecology: The experimental analysis of distribution and abundance*. (5th ed.). Benjamin Cummings.

Larsson, I. & Sytsma, M. (October, 2006). *Ballast water management on the Columbia River.* Retrieved May 5, 2007 from http://www.psparchives.com/publications /our_work/protect_habitat/ballast_water/ColumbiaRiverBWReportFinal.pdf

Mackey, T.P., Tagg, R.D. & Parsons, M.G. (2000). *8th ICMES/SNAME New York Metropolitan Section Symposium ~ Technologies for ballast water management*. May 22-23, 2000. Retrieved September 4, 2007 from http://www.optimarin.com/ PDF_Files/BW_ICMES_Mar_30_Final.pdf

Mackey, T. P. (December, 2005). *Ballast water treatment technologies: Including a review of initial testing and lessons learned aboard the Regal Princess*. Retrieved June 20, 2007 from http://www.optimarin.com/PDF_Files/TPM_MEETS_Final.pdf

Markovina, R., Blagojević, B. & Ban, D. (October 5, 2007). Druzhba Adria Project – Managing ballast water problems. *Zaštita Morskog Okoliša. Naše more*. 2007 (54). 227-232. Retrieved June 30, 2008 from http://hrcak.srce.hr/file/27903

Meyrick & Associates Pty Ltd. (March, 2003). *Evaluation of the Hastings National Demonstration Project*. Retrieved May 14, 2007 from https://www.epa.vic.gov.au /water/ballastwater/docs/Hastings_Evaluation_Report_June_03.pdf

MITSG Massachusetts Institute of Technology Sea Grant. (November, 14, 2006). *Marine bio invasions fact sheet: Ballast water treatment options*. Retrieved December, 4, 2006 from http://massbay.mit.edu/ resources/pdf/ballast-treat.pdf.

MSDTC Marine Safety Directorate Transport Canada. (March, 2004). *Small commercial vessel safety guide*. Retrieved November 4, 2006 from http://www.tc.gc.ca/marinesafety/Tp/tp14070/11-vessel-stability.htm

NOAA National Oceanic and Atmospheric Administration. (2004). *Assessment of transoceanic NOBOB (no-ballaston-board) vessels and low-salinity ballast water as vectors for nonindigenous species introductions to the Great Lakes*. Retrieved May 7, 2008 from http://www.glerl.noaa.gov/res/Task_rpts/2004/nobob1.pdf

Oemcke, D. (1999). The treatment of ships' ballast water. *Ecoports Monograph*. Series No.18 (Ports Corporation of Queensland, Brisbane), 102 pp.

Official Gazette. (September 01, 1922). *Law on Ports*. No.618 (01.09.1922 tarih ve 618 sayılı Limanlar Kanunu)

Official Gazette. (December 12, 1986). *The addendum of the Governmental Decree on the Turkish Exclusive Economic Zone.* No. 86-11264 (5.12.1986 tarihli ve 86-11264 sayılı Kararnamenin eki Türk Münhasir Ekonomik Bölgesi Hakkında Karar)

Olgun, A. (March 27, 2007). Balast Suyu ile Taşınan Zararlı Sucul Organizmaların Kontrolü ve Yönetimi. TÜBİTAK MAM KÇE, Trabzon. Powerpoint Presentation.

Özel, İ. (2000). *Planktonoloji I: Plankton ekolojisi ve araştırma yöntemleri*. (3rd ed.) İzmir: Ege Üniversitesi.

Pederson, J. (September 26, 2002). *Massachusetts Institute of Technology Sea Grant Program ~ Ballast water management workshop: Regional solutions*. Retrieved April 11, 2007 from http://massbay.mit.edu/publications/ballastwater/BallastWaterManagement-2002.pdf

PBWG (Pacific Ballast Water Group). (June 4, 2005). *Working Draft Report and Recommendations.* Retrieved December 9, 2006, from http://www.clr.pdx.edu/ projects/ballast_water/pbwg/docs

PV Parliament of Victoria. (March 1, 2002). *Report on ballast water and hull fouling in Victoria*. Retrieved October 16, 2006, from http://www.parliament.vic.gov.au/enrc/ inquiries/old/enrc/ballast/Ballast

PWSRCAC Prince William Sound Regional Citizens' Advisory Council. (January 29, 2005a). *Ballast water treatment methods. Fact sheet 2 Shore-based treatment.* Retrieved June 7, 2007 from http://www.pwsrcac.org/docs/ d0017000.pdf

PWSRCAC (January 29, 2005b). *Ballast Water Treatment Methods. Fact Sheet 11 Chemical Biocides.* Retrieved July 17, 2006 from http://www.pwsrcac.org/ docs/d0017900.pdf

PWSRCAC (January 29, 2005c). *Ballast Water Treatment Methods. Fact Sheet 12 Physical Separation.* Retrieved July 15, 2006 from http://www.pwsrcac.org/ docs/d0018000.pdf

PWSRCAC. (January 29, 2005d). *Ballast water treatment methods. Fact sheet 14 Electric field technology-pulsed and plasma.* Retrieved February 20, 2007 from http://www.pwsrcac.org/docs/d0018200.pdf

PWSRCAC. (February 3, 2005e). *Ballast water treatment methods. Fact sheet 8 Thermal treatment.* Retrieved March 27, 2007 from http://www.pwsrcac.org/docs/ d0017600.pdf

PWSRCAC. (February 3, 2005f). *Ballast water treatment methods. Fact sheet 9 Deoxygenation.* Retrieved May 16, 2007 from http://www.pwsrcac.org/docs/ d0017700.pdf

Raaymakers, S. (2002). *RECSO / IMO Joint Seminar on Tanker Ballast Water Management & Technologies ~ The ballast water problem: Global ecological, economic and human health impacts*. Retrieved December 16, 2006 from http://www.imo.org/includes/blastData.asp/doc_id=3400/Raaymakers%20Global%20 Impacts%20Paper.pdf

Republic of Turkiye, Ministry of Environment and Forestry. (2006). *The environmental impact assessment of the coastal constructions. Sector guide*. Retrieved June 17, 2008 from http://www.cevreorman.gov.tr/cedbim/Documents/6%20-20Sectoral%20 guideline%20%20coastal%20structures%20(TR).pdf

Republic of Turkiye, The Undersecretariat for Maritime Affairs. (2006). *Control and management of harmful aquatic organisms carried with ballast water.* Retrieved March 4, 2007 from
http://www.denizcilik.gov.tr/tr/Dosyalar/balast_suyu.

Rotatek (2009). *Antrasit.* Retrieved July 13, 2009 from http://www.rotatek.com.tr/ antrasit.htm

Rygh, K. (November, 2007). *Ballast water management. Procedures and equipment. Status and prospects*. Retrieved May, 17, 2008 from http://www.dnv.ee/Binaries/ Ballast%20water%20managementi_tcm75-265252.pdf

Seaport Haber. (28 Haziran 2009). *Aliağa Nemrut Körfezi'ne 5 yeni liman*. Retrieved July 4, 2009 from http://www.seaporthaber.com/aliaga-nemrut-korfezine-5-yeni-liman-haber,1452.html

SFC The Shipping Federation of Canada. (September 28, 2000). *Code of best practices for ballast water management*. Retrieved March 07, 2007 from http://www.shipfed.ca/eng/library/other_subjects/ballats_water/BallastWaterBestPractices.html

Shine, C. & Klemm, C. (1999). *IUCN Environmental Law Centre. Paper No.38 Wetlands, water and the law*. Retrieved August 25, 2008 from http://books.google.com/books?hl=en&id=vbdHSAuybRkC&dq=wetlands,+water+and+the+law&printsec=frontcover&source=web&ots=gbldDbdFEb&sig=_TtFRyF6Ep8uQt95zYAKA_j-dEI&sa=X&oi=book_result&resnum=1&ct=result#PPP17,M1

Snelgrove, P.V.R. (2001). Marine Sediments. *Encyclopedia of Biodiversity*. New York: Academic Press. (4), 71-84.

Sucu, K. (February 4, 2008). Personel interview. Pilot Captain, Aliağa.

SWOSC Surface Warfare Officers School Command, (March, 2000). *Stability*. Retrieved August 4, 2006 from http://www.dcfp.navy.mil/train/swos.htm

SWRCB-CEPA State Water Resources Control Board California Environmental Protection Agency (December, 2002). *Evaluation of ballast water treatment technology for control of nonindigenous aquatic organisms*. Retrieved August 25, 2005 from http://www.calepa.ca.gov/Publications/Reports/Mandated/2002/Ballast Water.pdf

Tamburri, M.N., Little, B.J., Ruiz, G.M., Lee, J.S. & McNulty, P.D. (2003). *Evaluations of Venturi Oxygen Stripping™ as a ballast water treatment to prevent aquatic invasions and ship corrosion.* Retrieved March 2, 2007 from http://www.nei-marine.com/documents/IMO_2003.pdf

Taylor, H. A. & Rigby, G. (January, 2001). *Suggested designs to facilitate improved management and treatment of ballast water on new and existing ships*. Retrieved August 21, 2007 from http://www.daff.gov.au/__data/assets/pdf_file/0018/23661/rep12.pdf

UC/ANR University of California Agriculture and Natural Resources. (2008). *West coast ballast outreach project*. Retrieved July 17, 2008 from http://groups.ucanr.org/Ballast_Outreach/Non-Ballast_Vessel_Vectors/Sea_Chests.htm

UF/IFAS University of Florida Institute of Food and Agricultural Sciences. (2007). Caulerpa Taxifolia. Retrieved May 21, 2007 from http://plants.ifas.ufl.edu/seagrant /cautax2.html

Üner, E.E. (February 4, 2008). Personel interview. Chief Enginner, M/T Ottoman Dignity

Waite, T.D., Kazumi, J., Lane, P.V.Z., Farmer, L.L., Smith, S.G., Smith, S.L., et al. (2003). Removal of natural populations of marine plankton by a large-scale ballast water treatment system. *Marine Ecology Progress Series*. 2003 (258), 51–63

Wikimedia Foundation Inc. (2007). *Seawater.* Retrieved November 12, 2008 from http://en.wikipedia.org/wiki/Sea_water

Wikimedia Foundation Inc. (2008a). *Zooplankton*. Retrieved November 3, 2008 from http://en.wikipedia.org/wiki/Zooplankton

Wikimedia Foundation Inc. (2008b). *Nekton*. Retrieved November 5, 2008 from http://en.wikipedia.org/wiki/Nekton

Wikimedia Foundation Inc. (2008c). *Plankton.* Retrieved November 6, 2008 from http://en.wikipedia.org/wiki/Plankton

Wikimedia Foundation Inc. (2008d). *Poisson Distribution.* Retrieved December 5, 2008 from http://en.wikipedia.org/wiki/Poisson_distribution

Wikimedia Foundation Inc. (2009). *Zeolit.* Retrieved May 29, 2009 from http://tr.wikipedia.org/ wiki/Zeolit

Wittenberg, R. & Cock, M.J.W., (Eds.). (2001). *Invasive alien species ~ How to address one of the greatest threats to biodiversity: A toolkit of best prevention and management practices*. Wallingford: CAB International. Retrieved April 19, 2005 from http://www.cabi-bioscience.ch/wwwgisp/gisp-toolkit.pdf

Yanmaz, A. M. (2001). *Applied water resources engineering*. (2nd ed.). Metu Press.

ANNEX I

Definitions of Terminology:

Anoxia: A total decrease in the level of oxygen, an extreme form of hypoxia or "low oxygen". (Wikipedia, 2008)

Benthic: Pertaining to the bottom of the sea or other aquatic environment.

Centre tank: Any tank inboard of a longitudinal bulkhead. (IMO, 2006)

Clean Ballast: The ballast in a tank which, since oil was last carried therein, has been so cleaned that effluent therefrom if it were discharged from a ship which is stationary into clean calm water on a clear day would not produce visible traces of oil on the surface of the water or on adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines. (IMO, 2006)

Clean Ballast Tank (CBT): Whereby specific cargo tanks are dedicated to carry ballast water only. (IMO, 2006)

Cleaning of Cargo Tanks: To wash the tanks out with water and then pump the resulting mixture of oil and water into the sea.

Crude Oil Washing (COW): The cleaning or washing of cargo tanks with high-pressure jets of crude oil. This reduces the quantity of oil remaining on board after discharge.

Eukaryotic organisms: Organisms whose cells are organized into complex structures enclosed within membranes.

Inert Gas System (IGS): Whereby exhaust gases, which are low in oxygen and thus incombustible, are used to replace flammable gases in tanks.

Invasive Species: Any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem; and whose introduction does or is likely to cause economic or environmental harm or harm to human health.

Load on Top: The washings resulting from tank cleaning are pumped into a special tank. During the voyage back to the loading terminal the oil and water separate. The water at the bottom of the tank is pumped overboard and at the terminal oil is pumped on to the oil left in the tank.

Protectively Located (PL): Placed in areas of the ship where they will minimize the possibility of and amount of oil outflow from cargo tanks after a collision or grounding.

Resting Stages: The life cycles of many aquatic plants, invertebrate animals, and microbes include the capability of producing resting stages (eggs, cysts, spores), which are extremely resistant to conditions such as lack of oxygen, exposure to toxic chemicals, low and high temperatures, and even survive passage through the digestive systems of fish and waterfowl. Resting stages may remain in sediment in a state of virtual suspended animation for decades or even centuries. Once exposed to the right combination of favorable environmental conditions, they can hatch or germinate to produce live organisms capable of reproducing. (NOAA, 2004)

Segregated ballast: The ballast water introduced into a tank which is completely separated from the cargo oil and oil fuel system and which is permanently allocated to the carriage of ballast or cargoes other than oil or noxious liquid substances. (IMO, 2006)

Slop tank: A tank specifically designated for the collection of tank drainings, tank washings and other oily mixtures.

Special Area: A sea area where for recognized technical reasons in relation to its oceanographical and ecological condition and to the particular character of its traffic the adoption of special mandatory methods for the prevention of sea pollution by oil is required. (IMO, 2006)

Upwelling: Upward vertical movement of water through the bottom of the surface mixed layer produced by a divergence at the surface.

Wing tank: Any tank adjacent to the side shell plating. (IMO, 2006)

ANNEX II

BALLAST TANKS																		G_0M	Estimated Drafts	
FP	NO 1 DB		NO 2 DB		NO 5 DB		NO 1 TST		NO 2 TST		NO 3 TST		NO 4 TST		NO 5 TST		AP			
C	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	C		Frw	Aft
F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	1.64	2.81	7.66
1. Step (Fore peak And Aft Peak pumping out at the same time)																				
E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	E	1.69	2.34	7.70
2. Step (Fore peak And Aft Peak refill again)																				
C	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	C	1.64	2.81	7.66
3. Step (No 1 DB AND No 5 TST Port & Stb pumping out)																				
C	E	E	F	F	F	F	F	F	F	F	F	F	F	F	E	E	C	1.69	2.44	7.40
4. Step (No 1 DB AND No 5 TST Port & Stb refill)																				
C	C	C	F	F	F	F	F	F	F	F	F	F	F	F	C	C	C	1.64	2.81	7.66
5. Step (No 2 DB AND NO 4 TST Port & Stb pumping out)																				
C	C	C	E	E	F	F	F	F	F	F	F	F	E	E	C	C	C	1.51	2.07	7.57
6. Step (No 2 DB Ve NO 4 TST Port & Stb refill)																				
C	C	C	C	C	F	F	F	F	F	F	F	F	C	C	C	C	C	1.64	2.81	7.66
7. Step (No 5 DB AND No 1 TST Port & Stb pumping out)																				
C	C	C	C	C	E	E	E	E	F	F	F	F	C	C	C	C	C	1.50	2.69	7.13
8. Step (No 5 DB AND No 1 TST Port & Stb refill)																				
C	C	C	C	C	C	C	C	C	F	F	F	F	C	C	C	C	C	1.64	2.81	7.66
9. Step (No 2 TST Port & Stb pumping out)																				
C	C	C	C	C	C	C	C	C	E	E	F	F	C	C	C	C	C	1.81	2.36	7.80
10. Step (No 2 TST Port & Stb refill)																				
C	C	C	C	C	C	C	C	C	C	C	F	F	C	C	C	C	C	1.64	2.81	7.66
11. Step (No 3 TST Port & Stb pumping out)																				
C	C	C	C	C	C	C	C	C	C	C	E	E	C	C	C	C	C	1.65	2.90	7.60
12. Step (No 3 TST Port & Stb refill)																				
C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	1.64	2.81	7.66

P.S.: It takes 24 hours with two pumps.

F Full Tank S Slack Tank E Empty Tank C Changed full Tank G_oM = GM (Reduced free surface effect)

ANNEX III

BALLAST WATER REPORTING FORM

(To be provided to the Port State Authority upon request)

1. SHIP INFORMATION			**2. BALLAST WATER**
Ship's Name:	Type:	IMO Number:	Specify Units: M^3, MT, LT, ST
Owner:	Gross Tonnage:	Call Sign:	Total Ballast Water on Board:
Flag:	Arrival Date:	Agent:	
Last Port and Country:		Arrival Port:	Total Ballast Water Capacity:
Next Port and Country:			

3. BALLAST WATER TANKS

Ballast Water Management Plan on board? YES NO

Management Plan Implemented? YES NO

Total number of ballast tanks on board : _______________

No. of tanks in ballast : _______________ IF NONE IN BALLAST GO TO No. 5.

No. of tanks exchanged : _______________

No. of tanks not exchanged : _______________

4. BALLAST WATER HISTORY: RECORD ALL TANKS THAT WILL BE DEBALLASTED IN PORT STATE OF ARRIVAL; IF NONE GO TO No. 5.

Tanks/ Holds	**BALLAST WATER SOURCE**				**BALLAST WATER EXCHANGE** Circle one: Empty/Refill or Flow Through					**BALLAST WATER DISCHARGE**			
(List multiple sources per tank separately)	DATE DDMMYY	Port or Lat/Long	Volume (units)	Temp (units)	DATE DDMMYY	Endpoint Lat/Long.	Volume (units)	% Exch.	Sea Hgt. (m)	DATE DDMMYY	Port or Lat/Long	Volume (units)	Salinity (units)
FP													
NO .. DB													
NO .. DB													
NO .. DB													
NO .. TS													
NO .. TS													
NO .. TS													
NO .. WT													
NO .. WT													
AP													
NO .. CH													

Ballast Water Tank Codes: Forepeak = FP, Aftpeak = AP; Double Bottom = DB; Wing = WT; Topside = TS; Cargo Hold = CH; Other = O

IF EXCHANGES WERE NOT CONDUCTED, STATE OTHER CONTROL ACTION(S) TAKEN:____

IF NONE STATE REASON WHY NOT:____

5: IMO BALLAST WATER GUIDELINES ON BOARD (RES. A.868(20))? YES NO

RESPONSIBLE OFFICER'S NAME AND TITLE (PRINTED) AND SIGNATURE:

ANNEX IV

List of ballast water management systems which received Type Approval Certification*

Name of the system	Name of manufacturer	Administration issuing Type Approval Certificate	Date of Certification
PureBallast System	Alfa Laval / Wallenius Water AB	Norway	June 2008
SEDNA® Ballast Water Management System (Using Peraclean® Ocean)	Degussa Gmbh, Germany	Germany	June 2008

* This list was compiled based on the information provided by the respective Administrations.
(Source: H&K, 2008)

List of ballast water management systems that make use of Active Substances which received Basic Approval*

Name of the system and proposing country	Name of manufacturer	Date of Basic Approval
SEDNA® Ballast Water Management System (Using Peraclean® Ocean), Germany	Degussa Gmbh, Germany 24	March 2006
Electro-Clean (electrolytic disinfection) system (subsequently changed to Electro-Cleen™), the Republic of Korea	Techcross Ltd. and Korea Ocean Research and Development Institute (KORDI)	24 March 2006
Special Pipe Ballast Water Management System (combined with Ozone treatment), Japan	Japan Association of Marine Safety (JAMS)	13 October 2006
EctoSys™ electrochemical System, Sweden	Permascand AB, Sweden, subsequently acquired by RWO GmbH, Germany	13 October 2006
PureBallast System, Sweden	Alfa Laval/ Wallenius Water AB	13 July 2007
NK Ballast Water Treatment System, the Republic of Korea	NK Company Ltd., the Republic of Korea	13 July 2007
Hitachi Ballast Water Purification System (ClearBallast), Japan	Hitachi, Ltd. /Hitachi Plant Technologies, Ltd.	4 April 2008
Resource Ballast Technologies System, South Africa	Resource Ballast Technologies (Pty) Ltd.	4 April 2008
GloEn-Patrol™ Ballast Water Management System, the Republic of Korea	Panasia Co., Ltd.	4 April 2008
OceanSaver® Ballast Water Management System (OS BWMS), Norway	MetaFil AS	4 April 2008
TG Ballastcleaner and TG Environmentalguard System, Japan	The Toagosei Group (TG Corporation, Toagosei Co. Ltd. and Tsurumi Soda Co. Ltd.)	10 October 2008
Greenship's Ballast Water Management System, the Netherlands	Greenship Ltd	10 October 2008
Ecochlor® Ballast Water Treatment System, Germany	Ecochlor, INC, Acton, the United States	10 October 2008

*More comprehensive information regarding these systems is available in document BWM.2/Circ.16.
(Source: H&K, 2008)

List of ballast water management systems that make use of Active Substances which received Final Approval*

Name of the system and proposing country	Name of manufacturer	Date of Final Approval
PureBallast System, Norway	Alfa Laval / Wallenius Water AB	13 July 2007
SEDNA® Ballast Water Management System (Using Peraclean® Ocean), Germany	Degussa Gmbh, Germany	4 April 2008
Electro-Cleen™ System, the Republic of Korea	Techcross Ltd. and Korea Ocean Research and Development Institute (KORDI)	10 October 2008
OceanSaver® Ballast Water Management System (OS BWMS), Norway	MetaFil AS	10 October 2008

*More comprehensive information regarding these systems is available in document BWM.2/Circ.16.
(Source: H&K, 2008)

ANNEX V

Calculation details of discharging ballast quantities

Ballast Capacity of Vessels (m3)	Arrival Date (day)	Arrival Time (h)	Midnight - Arrival Time (h)	Midnight - Arrival Time (metric)	Departure - Arrival Time (metric)	1st Day Rate	2nd Day Rate	3rd Day Rate	Departure Date (h)	Departure Time (h)	Operation Days	1st day (m^3)	2nd day (m^3)	3rd day (m^3)
932,867	01.07.2007	02:15:00							01.07.2007	17:15:00	1	932,87	0,00	0,00
1894,667	01.07.2007	12:45:00	11:15:00	11,25	18,83	0,60	0,40		02.07.2007	07:35:00	2	1.131,77	762,90	0,00
1191,867	02.07.2007	03:45:00							02.07.2007	18:30:00	1	1.191,87	0,00	0,00
2086,467	02.07.2007	10:55:00	13:05:00	13,08	18,33	0,71	0,29		03.07.2007	05:15:00	2	1.488,98	597,49	0,00
1962,800	02.07.2007	19:00:00	05:00:00	5,00	19,42	0,26	0,74		03.07.2007	14:25:00	2	505,44	1.457,36	0,00
1397,200	03.07.2007	14:10:00	09:50:00	9,83	14,08	0,70	0,30		04.07.2007	04:15:00	2	975,56	421,64	0,00
1082,200	03.07.2007	19:35:00	04:25:00	4,42	24,75	0,18	0,82		04.07.2007	19:45:00	2	193,12	889,08	0,00
26213,600	04.07.2007	00:36:00	23:24:00	23,40	35,73	0,65	0,35		05.07.2007	12:20:00	2	17.166,00	9.047,60	0,00
11866,867	04.07.2007	12:25:00							04.07.2007	19:45:00	1	11.866,87	0,00	0,00
9275,000	05.07.2007	11:24:00	12:36:00	12,60	42,10	0,30	0,57	0,13	07.07.2007	05:30:00	3	2.775,89	5.287,41	1.211,70
24505,600	05.07.2007	13:12:00	10:48:00	10,80	48,83	0,22	0,49	0,29	07.07.2007	14:02:00	3	5.419,67	12.043,71	7.042,22
2331,933	05.07.2007	20:10:00	03:50:00	3,83	24,25	0,16	0,84		06.07.2007	20:25:00	2	368,62	1.963,31	0,00
1333,267	06.07.2007	11:00:00	13:00:00	13,00	28,58	0,45	0,55		07.07.2007	15:35:00	2	606,38	726,88	0,00
11866,867	07.07.2007	08:45:00	15:15:00	15,25	36,25	0,42	0,58		08.07.2007	21:00:00	2	4.992,27	6.874,60	0,00
1057,000	07.07.2007	15:00:00	09:00:00	9,00	16,50	0,55	0,45		08.07.2007	07:30:00	2	576,55	480,45	0,00
1962,800	07.07.2007	19:15:00	04:45:00	4,75	18,50	0,26	0,74		08.07.2007	13:45:00	2	503,96	1.458,84	0,00
349,067	07.07.2007	20:00:00	04:00:00	4,00	13,50	0,30	0,70		08.07.2007	09:30:00	2	103,43	245,64	0,00
932,867	08.07.2007	09:55:00	14:05:00	14,08	18,08	0,78	0,22		09.07.2007	04:00:00	2	726,52	206,35	0,00
2086,467	08.07.2007	14:20:00	09:40:00	9,67	21,42	0,45	0,55		09.07.2007	11:45:00	2	941,75	1.144,72	0,00
273,933	08.07.2007	18:45:00	05:15:00	5,25	15,75	0,33	0,67		09.07.2007	10:30:00	2	91,31	182,62	0,00
2127,067	08.07.2007	21:30:00	02:30:00	2,50	23,67	0,11	0,89		09.07.2007	21:10:00	2	224,69	1.902,38	0,00
1397,200	09.07.2007	04:20:00	19:40:00	19,67	26,42	0,74	0,26		10.07.2007	06:45:00	2	1.040,19	357,01	0,00
1191,867	09.07.2007	11:00:00							09.07.2007	21:00:00	1	1.191,87	0,00	0,00
11970,467	09.07.2007	16:06:00	07:54:00	7,90	31,10	0,25	0,75		10.07.2007	23:12:00	2	3.040,73	8.929,74	0,00
1066,800	10.07.2007	07:05:00	16:55:00	16,92	23,92	0,71	0,29		11.07.2007	07:00:00	2	754,57	312,23	0,00

1397,200	10.07.2007	14:15:00	09:45:00	9,75	26,25	0,37	0,63		11.07.2007	16:30:00	2	518,96	878,24	0,00
1082,200	11.07.2007	15:00:00	09:00:00	9,00	23,50	0,38	0,62		12.07.2007	14:30:00	2	414,46	667,74	0,00
349,533	11.07.2007	23:10:00	00:50:00	0,83	13,17	0,06	0,94		12.07.2007	12:20:00	2	22,12	327,41	0,00
1057,000	12.07.2007	07:30:00	16:30:00	16,50	23,83	0,69	0,31		13.07.2007	07:20:00	2	731,77	325,23	0,00
1638,467	12.07.2007	19:45:00	04:15:00	4,25	24,08	0,18	0,82		13.07.2007	19:50:00	2	289,14	1.349,33	0,00
2331,933	13.07.2007	00:20:00							13.07.2007	23:30:00	1	2.331,93	0,00	0,00
969,267	13.07.2007	16:45:00	07:15:00	7,25	23,50	0,31	0,69		14.07.2007	16:15:00	2	299,03	670,24	0,00
1962,800	13.07.2007	23:50:00	00:10:00	0,17	17,92	0,01	0,99		14.07.2007	17:45:00	2	18,26	1.944,54	0,00
1066,800	14.07.2007	03:00:00							14.07.2007	17:15:00	1	1.066,80	0,00	0,00
12235,067	15.07.2007	00:01:00	23:59:00	23,98	28,98	0,83	0,17		16.07.2007	05:00:00	2	10.124,36	2.110,71	0,00
1191,867	15.07.2007	01:45:00							15.07.2007	21:10:00	1	1.191,87	0,00	0,00
932,867	15.07.2007	22:30:00	01:30:00	1,50	22,33	0,07	0,93		16.07.2007	20:50:00	2	62,66	870,21	0,00
4089,400	16.07.2007	00:10:00	23:50:00	23,83	24,50	0,97	0,03		17.07.2007	00:40:00	2	3.978,12	111,28	0,00
1082,200	16.07.2007	23:40:00	00:20:00	0,33	22,83	0,01	0,99		17.07.2007	22:30:00	2	15,80	1.066,40	0,00
2127,067	17.07.2007	01:10:00							17.07.2007	19:30:00	1	2.127,07	0,00	0,00
1053,267	17.07.2007	07:00:00	17:00:00	17,00	57,00	0,30	0,42	0,28	19.07.2007	16:00:00	3	314,13	443,48	295,65
1066,800	18.07.2007	01:30:00							18.07.2007	22:15:00	1	1.066,80	0,00	0,00
26644,333	18.07.2007	22:54:00	01:06:00	1,10	19,75	0,06	0,94		19.07.2007	18:48:00	2	1.483,99	25.160,35	0,00
11853,333	19.07.2007	02:36:00	21:24:00	21,40	26,80	0,80	0,20		20.07.2007	05:24:00	2	9.464,98	2.388,36	0,00
1638,467	19.07.2007	07:10:00	16:50:00	16,83	34,58	0,49	0,51		20.07.2007	17:45:00	2	797,52	840,95	0,00
1057,000	19.07.2007	16:30:00	07:30:00	7,50	21,75	0,34	0,66		20.07.2007	14:15:00	2	364,48	692,52	0,00
1962,800	19.07.2007	19:20:00	04:40:00	4,67	25,17	0,19	0,81		20.07.2007	20:30:00	2	363,96	1.598,84	0,00
2086,467	20.07.2007	11:00:00	13:00:00	13,00	23,00	0,57	0,43		21.07.2007	10:30:00	2	1.179,31	907,16	0,00
2099,533	21.07.2007	02:50:00							21.07.2007	21:00:00	1	2.099,53	0,00	0,00
12892,600	21.07.2007	10:54:00	13:06:00	13,10	36,10	0,36	0,64		22.07.2007	23:00:00	2	4.678,48	8.214,12	0,00
2127,067	21.07.2007	21:45:00	02:15:00	2,25	18,08	0,12	0,88		22.07.2007	15:50:00	2	264,66	1.862,41	0,00
1066,800	22.07.2007	09:30:00							22.07.2007	19:30:00	1	1.066,80	0,00	0,00
932,867	22.07.2007	23:30:00	00:30:00	0,50	20,50	0,02	0,98		23.07.2007	20:00:00	2	22,75	910,11	0,00
1259,533	23.07.2007	00:10:00							23.07.2007	22:00:00	1	1.259,53	0,00	0,00
1047,200	23.07.2007	19:30:00	04:30:00	4,50	17,67	0,25	0,75		24.07.2007	13:10:00	2	266,74	780,46	0,00
4089,400	24.07.2007	02:20:00	21:40:00	21,67	25,42	0,85	0,15		25.07.2007	03:45:00	2	3.486,05	603,35	0,00
10657,733	24.07.2007	15:00:00	09:00:00	9,00	39,50	0,23	0,61	0,16	26.07.2007	06:30:00	3	2.428,34	6.475,58	1.753,80
1191,867	24.07.2007	16:40:00	07:20:00	7,33	20,17	0,36	0,64		25.07.2007	12:50:00	2	433,41	758,46	0,00
324,333	25.07.2007	18:40:00	05:20:00	5,33	11,67	0,46	0,54		26.07.2007	06:20:00	2	148,27	176,07	0,00

2086,467	26.07.2007	18:20:00	05:40:00	5,67	28,67	0,20	0,80		27.07.2007	23:00:00	2	412,44	1.674,03	0,00
1962,800	27.07.2007	07:20:00	16:40:00	16,67	23,50	0,71	0,29		28.07.2007	07:00:00	2	1.392,06	570,74	0,00
1259,533	27.07.2007	14:30:00	09:30:00	9,50	20,50	0,46	0,54		28.07.2007	11:00:00	2	583,69	675,85	0,00
1057,000	28.07.2007	00:20:00							28.07.2007	19:05:00	1	1.057,00	0,00	0,00
2046,800	28.07.2007	08:30:00	15:30:00	15,50	23,00	0,67	0,33		29.07.2007	07:30:00	2	1.379,37	667,43	0,00
651,467	28.07.2007	17:45:00	06:15:00	6,25	11,50	0,54	0,46		29.07.2007	05:15:00	2	354,06	297,41	0,00
1053,267	29.07.2007	13:00:00	11:00:00	11,00	15,17	0,73	0,27		30.07.2007	04:10:00	2	763,91	289,36	0,00
2392,600	29.07.2007	14:10:00	09:50:00	9,83	24,33	0,40	0,60		30.07.2007	14:30:00	2	966,87	1.425,73	0,00
932,867	29.07.2007	17:55:00	06:05:00	6,08	27,25	0,22	0,78		30.07.2007	21:10:00	2	208,25	724,61	0,00
2086,467	30.07.2007	10:15:00	13:45:00	13,75	18,25	0,75	0,25		31.07.2007	04:30:00	2	1.572,00	514,47	0,00
11903,267	30.07.2007	19:00:00	05:00:00	5,00	35,00	0,14	0,69	0,17	01.08.2007	06:00:00	3	1.700,47	8.162,24	2.040,56
1191,867	30.07.2007	21:35:00	02:25:00	2,42	19,92	0,12	0,88		31.07.2007	17:30:00	2	144,62	1.047,25	0,00
	31.07.2007											0,00	0,00	0,00
1057,000	01.08.2007	00:30:00							01.08.2007	17:00:00	1	1.057,00	0,00	0,00
23599,800	01.08.2007	13:54:00	10:06:00	10,10	42,80	0,24	0,56	0,20	03.08.2007	08:42:00	3	5.569,11	13.233,53	4.797,16
1962,800	01.08.2007	19:30:00	04:30:00	4,50	19,50	0,23	0,77		02.08.2007	15:00:00	2	452,95	1.509,85	0,00
1259,533	01.08.2007	20:00:00	04:00:00	4,00	18,67	0,21	0,79		02.08.2007	14:40:00	2	269,90	989,63	0,00
2405,200	02.08.2007	15:25:00	08:35:00	8,58	19,17	0,45	0,55		03.08.2007	10:35:00	2	1.077,11	1.328,09	0,00
2046,800	03.08.2007	09:25:00	14:35:00	14,58	14,67	0,99	0,01		04.08.2007	00:05:00	2	2.035,17	11,63	0,00
932,867	03.08.2007	15:30:00	08:30:00	8,50	18,00	0,47	0,53		04.08.2007	09:30:00	2	440,52	492,35	0,00
1638,467	03.08.2007	22:50:00	01:10:00	1,17	19,75	0,06	0,94		04.08.2007	18:35:00	2	96,79	1.541,68	0,00
1151,267	04.08.2007	00:30:00							04.08.2007	13:35:00	1	1.151,27	0,00	0,00
2392,600	04.08.2007	21:30:00	02:30:00	2,50	23,25	0,11	0,89		05.08.2007	20:45:00	2	257,27	2.135,33	0,00
1397,200	04.08.2007	23:20:00	00:40:00	0,67	21,17	0,03	0,97		05.08.2007	20:30:00	2	44,01	1.353,19	0,00
651,467	05.08.2007	10:35:00							05.08.2007	21:45:00	1	651,47	0,00	0,00
3552,733	05.08.2007	19:35:00	04:25:00	4,42	23,58	0,19	0,81		06.08.2007	19:10:00	2	665,35	2.887,38	0,00
2086,467	06.08.2007	00:30:00							06.08.2007	22:45:00	1	2.086,47	0,00	0,00
1057,000	06.08.2007	16:30:00	07:30:00	7,50	19,50	0,38	0,62		07.08.2007	12:00:00	2	406,54	650,46	0,00
1962,800	07.08.2007	04:20:00	19:40:00	19,67	22,17	0,89	0,11		08.08.2007	02:30:00	2	1.741,43	221,37	0,00
4089,400	07.08.2007	11:10:00	12:50:00	12,83	30,58	0,42	0,58		08.08.2007	17:45:00	2	1.715,99	2.373,41	0,00
1191,867	07.08.2007	12:30:00							07.08.2007	21:45:00	1	1.191,87	0,00	0,00
2046,800	08.08.2007	05:45:00							08.08.2007	23:45:00	1	2.046,80	0,00	0,00
1392,067	08.08.2007	07:30:00	16:30:00	16,50	33,25	0,50	0,50		09.08.2007	16:45:00	2	690,80	701,27	0,00
11836,533	09.08.2007	14:54:00	09:06:00	9,10	35,77	0,25	0,67	0,07	11.08.2007	02:40:00	3	3.011,53	7.942,50	882,50

1638,467	09.08.2007	23:45:00	00:15:00	0,25	28,67	0,01	0,84	0,15	11.08.2007	04:25:00	3	14,29	1.371,74	252,44
2099,533	10.08.2007	09:10:00	14:50:00	14,83	19,50	0,76	0,24		11.08.2007	04:40:00	2	1.597,08	502,45	0,00
8630,067	11.08.2007	03:14:00	20:46:00	20,77	20,77	1,00	0,00		12.08.2007	20:00:00	2	8.630,07	0,00	0,00
1902,133	11.08.2007	05:00:00	19:00:00	19,00	21,58	0,88	0,12		12.08.2007	02:35:00	2	1.674,46	227,67	0,00
1082,200	11.08.2007	19:20:00	04:40:00	4,67	25,50	0,18	0,82		12.08.2007	20:50:00	2	198,05	884,15	0,00
14037,800	12.08.2007	03:30:00	20:30:00	20,50	37,33	0,55	0,45		13.08.2007	16:50:00	2	7.708,26	6.329,54	0,00
1151,267	12.08.2007	20:20:00	03:40:00	3,67	23,75	0,15	0,85		13.08.2007	20:05:00	2	177,74	973,53	0,00
1191,867	12.08.2007	21:15:00	02:45:00	2,75	19,25	0,14	0,86		13.08.2007	16:30:00	2	170,27	1.021,60	0,00
932,867	13.08.2007	17:20:00	06:40:00	6,67	19,50	0,34	0,66		14.08.2007	12:50:00	2	318,93	613,94	0,00
2046,800	13.08.2007	20:15:00	03:45:00	3,75	21,92	0,17	0,83		14.08.2007	18:10:00	2	350,21	1.696,59	0,00
1057,000	14.08.2007	00:40:00							14.08.2007	17:25:00	1	1.057,00	0,00	0,00
2392,600	14.08.2007	13:05:00	10:55:00	10,92	16,00	0,68	0,32		15.08.2007	05:05:00	2	1.632,45	760,15	0,00
1397,200	14.08.2007	17:50:00	06:10:00	6,17	25,67	0,24	0,76		15.08.2007	19:30:00	2	335,69	1.061,51	0,00
1962,800	14.08.2007	23:00:00	01:00:00	1,00	19,08	0,05	0,95		15.08.2007	18:05:00	2	102,85	1.859,95	0,00
1047,200	15.08.2007	05:40:00	18:20:00	18,33	20,83	0,88	0,12		16.08.2007	02:30:00	2	921,54	125,66	0,00
651,467	16.08.2007	00:20:00							16.08.2007	13:00:00	1	651,47	0,00	0,00
2086,467	16.08.2007	02:50:00	21:10:00	21,17	26,67	0,79	0,21		17.08.2007	05:30:00	2	1.656,13	430,33	0,00
24600,800	16.08.2007	03:24:00	20:36:00	20,60	21,00	0,98	0,02		17.08.2007	00:24:00	2	24.132,21	468,59	0,00
1638,467	16.08.2007	13:15:00	10:45:00	10,75	24,00	0,45	0,55		17.08.2007	13:15:00	2	733,90	904,57	0,00
11857,067	17.08.2007	20:30:00	03:30:00	3,50	24,60	0,14	0,86		18.08.2007	21:06:00	2	1.686,98	10.170,09	0,00
1191,867	18.08.2007	02:15:00							18.08.2007	23:30:00	1	1.191,87	0,00	0,00
2099,533	18.08.2007	11:50:00	12:10:00	12,17	19,67	0,62	0,38		19.08.2007	07:30:00	2	1.298,86	800,67	0,00
4089,400	18.08.2007	21:50:00	02:10:00	2,17	22,92	0,09	0,91		19.08.2007	20:45:00	2	386,63	3.702,77	0,00
2086,467	19.08.2007	08:10:00	15:50:00	15,83	20,33	0,78	0,22		20.08.2007	04:30:00	2	1.624,71	461,76	0,00
1397,200	19.08.2007	13:40:00	10:20:00	10,33	23,83	0,43	0,57		20.08.2007	13:30:00	2	605,78	791,42	0,00
8415,400	19.08.2007	21:24:00	02:36:00	2,60	33,27	0,08	0,72	0,20	21.08.2007	06:40:00	3	657,72	6.071,23	1.686,45
10859,333	20.08.2007	11:35:00	12:25:00	12,42	36,92	0,34	0,65	0,01	22.08.2007	00:30:00	3	3.652,46	7.059,79	147,08
1082,200	20.08.2007	13:45:00	10:15:00	10,25	11,50	0,89	0,11		21.08.2007	01:15:00	2	964,57	117,63	0,00
932,867	21.08.2007	01:55:00							21.08.2007	21:45:00	1	932,87	0,00	0,00
2392,600	21.08.2007	07:10:00	16:50:00	16,83	18,67	0,90	0,10		22.08.2007	01:50:00	2	2.157,61	234,99	0,00
1151,267	21.08.2007	22:00:00	02:00:00	2,00	28,00	0,07	0,86	0,07	23.08.2007	02:00:00	3	82,23	986,80	82,23
2046,800	22.08.2007	22:00:00	02:00:00	2,00	22,00	0,09	0,91		23.08.2007	20:00:00	2	186,07	1.860,73	0,00
1191,867	23.08.2007	08:10:00	15:50:00	15,83	28,83	0,55	0,45		24.08.2007	13:00:00	2	654,49	537,37	0,00
1045,333	23.08.2007	08:45:00	15:15:00	15,25	32,25	0,47	0,53		24.08.2007	17:00:00	2	494,30	551,03	0,00

26751,667	24.08.2007	06:24:00	17:36:00	17,60	39,20	0,45	0,55		25.08.2007	21:36:00	2	12.010,95	14.740,71	0,00
1082,200	25.08.2007	11:50:00	12:10:00	12,17	25,25	0,48	0,52		26.08.2007	13:05:00	2	521,46	560,74	0,00
1638,467	25.08.2007	12:25:00	11:35:00	11,58	24,67	0,47	0,53		26.08.2007	13:05:00	2	769,42	869,05	0,00
10843,467	25.08.2007	22:24:00	01:36:00	1,60	28,18	0,06	0,85	0,09	27.08.2007	02:35:00	3	615,60	9.233,94	993,93
2127,067	26.08.2007	16:15:00	07:45:00	7,75	17,50	0,44	0,56		27.08.2007	09:45:00	2	941,99	1.185,08	0,00
17679,200	27.08.2007	03:30:00	20:30:00	20,50	39,25	0,52	0,48		28.08.2007	18:45:00	2	9.233,72	8.445,48	0,00
1397,200	27.08.2007	21:35:00	02:25:00	2,42	14,17	0,17	0,83		28.08.2007	11:45:00	2	238,35	1.158,85	0,00
1191,867	28.08.2007	21:40:00	02:20:00	2,33	17,58	0,13	0,87		29.08.2007	15:15:00	2	158,16	1.033,70	0,00
932,867	29.08.2007	15:35:00	08:25:00	8,42	13,92	0,60	0,40		30.08.2007	05:30:00	2	564,19	368,68	0,00
18995,667	29.08.2007	17:06:00	06:54:00	6,90	29,40	0,23	0,77		30.08.2007	22:30:00	2	4.458,17	14.537,50	0,00
1305,733	29.08.2007	22:30:00	01:30:00	1,50	14,83	0,10	0,90		30.08.2007	13:20:00	2	132,04	1.173,69	0,00
8415,400	30.08.2007	13:35:00	10:25:00	10,42	39,42	0,26	0,61	0,13	01.09.2007	05:00:00	3	2.223,94	5.123,96	1.067,49
2046,800	30.08.2007	23:15:00	00:45:00	0,75	18,00	0,04	0,96		31.08.2007	17:15:00	2	85,28	1.961,52	0,00
1397,200	31.08.2007	09:45:00	14:15:00	14,25	29,42	0,48	0,52		01.09.2007	15:10:00	2	676,83	720,37	0,00
1962,800	31.08.2007	21:30:00	02:30:00	2,50	34,00	0,07	0,71	0,22	02.09.2007	07:30:00	3	144,32	1.385,51	432,97
2127,067	01.09.2007	05:35:00	18:25:00	18,42	21,42	0,86	0,14		02.09.2007	03:00:00	2	1.829,11	297,95	0,00
1638,467	01.09.2007	15:30:00	08:30:00	8,50	17,42	0,49	0,51		02.09.2007	08:55:00	2	799,63	838,83	0,00
1259,533	02.09.2007	03:25:00							02.09.2007	22:50:00	1	1.259,53	0,00	0,00
2086,467	02.09.2007	08:10:00	15:50:00	15,83	19,75	0,80	0,20		03.09.2007	03:55:00	2	1.672,69	413,77	0,00
1397,200	02.09.2007	09:25:00	14:35:00	14,58	21,25	0,69	0,31		03.09.2007	06:40:00	2	958,86	438,34	0,00
2104,200	03.09.2007	04:20:00							03.09.2007	22:00:00	1	2.104,20	0,00	0,00
13318,200	03.09.2007	11:24:00							03.09.2007	18:30:00	1	13.318,20	0,00	0,00
1082,200	03.09.2007	19:25:00	04:35:00	4,58	21,33	0,21	0,79		04.09.2007	16:45:00	2	232,50	849,70	0,00
1191,867	04.09.2007	00:30:00							04.09.2007	18:30:00	1	1.191,87	0,00	0,00
13318,200	04.09.2007	17:20:00	06:40:00	6,67	30,77	0,22	0,78	0,00	06.09.2007	00:06:00	3	2.885,85	10.389,06	43,29
2099,533	04.09.2007	21:05:00	02:55:00	2,92	20,25	0,14	0,86		05.09.2007	17:20:00	2	302,40	1.797,13	0,00
1305,733	05.09.2007	07:20:00							05.09.2007	21:30:00	1	1.305,73	0,00	0,00
739,200	05.09.2007	22:00:00	02:00:00	2,00	20,50	0,10	0,90		06.09.2007	18:30:00	2	72,12	667,08	0,00
4089,400	06.09.2007	00:55:00	23:05:00	23,08	37,75	0,61	0,39		07.09.2007	14:40:00	2	2.500,58	1.588,82	0,00
9866,267	06.09.2007	21:35:00	02:25:00	2,42	38,42	0,06	0,62	0,31	08.09.2007	12:00:00	3	620,65	6.163,74	3.081,87
2046,800	07.09.2007	15:45:00	08:15:00	8,25	18,00	0,46	0,54		08.09.2007	09:45:00	2	938,12	1.108,68	0,00
11222,400	08.09.2007	10:30:00	13:30:00	13,50	38,33	0,35	0,63	0,02	10.09.2007	00:50:00	3	3.952,24	7.026,20	243,97
11844,933	08.09.2007	12:42:00	11:18:00	11,30	25,47	0,44	0,56		09.09.2007	14:10:00	2	5.255,80	6.589,13	0,00
1191,867	09.09.2007	13:10:00	10:50:00	10,83	21,58	0,50	0,50		10.09.2007	10:45:00	2	598,23	593,63	0,00

2086,467	09.09.2007	16:15:00	07:45:00	7,75	21,25	0,36	0,64		10.09.2007	13:30:00	2	760,95	1.325,52	0,00
1305,733	10.09.2007	01:30:00							10.09.2007	21:50:00	1	1.305,73	0,00	0,00
1638,467	10.09.2007	11:15:00	12:45:00	12,75	30,83	0,41	0,59		11.09.2007	18:05:00	2	677,53	960,94	0,00
12012,000	11.09.2007	11:12:00	12:48:00	12,80	34,88	0,37	0,63		12.09.2007	22:05:00	2	4.407,65	7.604,35	0,00
1397,200	12.09.2007	05:10:00	18:50:00	18,83	20,67	0,91	0,09		13.09.2007	01:50:00	2	1.273,25	123,95	0,00
1082,200	12.09.2007	09:40:00	14:20:00	14,33	17,17	0,83	0,17		13.09.2007	02:50:00	2	903,58	178,62	0,00
1259,533	12.09.2007	22:30:00	01:30:00	1,50	23,75	0,06	0,94		13.09.2007	22:15:00	2	79,55	1.179,98	0,00
1047,200	13.09.2007	09:10:00	14:50:00	14,83	22,08	0,67	0,33		14.09.2007	07:15:00	2	703,40	343,80	0,00
651,467	13.09.2007	22:30:00	01:30:00	1,50	16,25	0,09	0,91		14.09.2007	14:45:00	2	60,14	591,33	0,00
	14.09.2007											0,00	0,00	0,00
2086,467	15.09.2007	09:35:00	14:25:00	14,42	19,67	0,73	0,27		16.09.2007	05:15:00	2	1.529,49	556,98	0,00
1191,867	15.09.2007	10:00:00	14:00:00	14,00	17,58	0,80	0,20		16.09.2007	03:35:00	2	948,97	242,89	0,00
739,200	16.09.2007	03:55:00							16.09.2007	15:30:00	1	739,20	0,00	0,00
2046,800	16.09.2007	06:30:00							16.09.2007	22:30:00	1	2.046,80	0,00	0,00
1397,200	16.09.2007	23:00:00	01:00:00	1,00	20,00	0,05	0,95		17.09.2007	19:00:00	2	69,86	1.327,34	0,00
2099,533	17.09.2007	12:45:00	11:15:00	11,25	21,67	0,52	0,48		18.09.2007	10:25:00	2	1.090,14	1.009,39	0,00
1962,800	17.09.2007	20:10:00	03:50:00	3,83	28,83	0,13	0,83	0,03	19.09.2007	01:00:00	3	260,95	1.633,78	68,07
26715,733	18.09.2007	11:30:00	12:30:00	12,50	27,00	0,46	0,54		19.09.2007	14:30:00	2	12.368,40	14.347,34	0,00
1082,200	19.09.2007	04:00:00	20:00:00	20,00	28,17	0,71	0,29		20.09.2007	08:10:00	2	768,43	313,77	0,00
739,200	19.09.2007	09:15:00							19.09.2007	18:30:00	1	739,20	0,00	0,00
2086,467	20.09.2007	07:30:00	16:30:00	16,50	16,83	0,98	0,02		21.09.2007	00:20:00	2	2.045,15	41,32	0,00
1259,533	20.09.2007	16:15:00	07:45:00	7,75	24,00	0,32	0,68		21.09.2007	16:15:00	2	406,72	852,81	0,00
12117,467	21.09.2007	06:48:00	17:12:00	17,20	34,70	0,50	0,50		22.09.2007	17:30:00	2	6.006,35	6.111,11	0,00
1397,200	22.09.2007	07:35:00	16:25:00	16,42	26,58	0,62	0,38		23.09.2007	10:10:00	2	862,85	534,35	0,00
2086,467	22.09.2007	18:10:00	05:50:00	5,83	28,17	0,21	0,79		23.09.2007	22:20:00	2	432,11	1.654,36	0,00
1136,333	23.09.2007	10:40:00	13:20:00	13,33	19,75	0,68	0,32		24.09.2007	06:25:00	2	767,14	369,19	0,00
10834,600	23.09.2007	20:50:00	03:10:00	3,17	30,92	0,10	0,78	0,12	25.09.2007	03:45:00	3	1.109,74	8.410,69	1.314,17
4089,400	23.09.2007	22:45:00	01:15:00	1,25	36,00	0,03	0,67	0,30	25.09.2007	10:45:00	3	141,99	2.726,27	1.221,14
932,867	24.09.2007	06:50:00	17:10:00	17,17	24,25	0,71	0,29		25.09.2007	07:05:00	2	660,38	272,49	0,00
2046,800	25.09.2007	06:35:00	17:25:00	17,42	24,25	0,72	0,28		26.09.2007	06:50:00	2	1.470,04	576,76	0,00
1191,867	25.09.2007	07:30:00	16:30:00	16,50	23,42	0,70	0,30		26.09.2007	07:05:00	2	839,82	352,05	0,00
2104,200	25.09.2007	11:05:00	12:55:00	12,92	18,67	0,69	0,31		26.09.2007	05:45:00	2	1.456,03	648,17	0,00
2086,467	26.09.2007	06:15:00	17:45:00	17,75	21,25	0,84	0,16		27.09.2007	03:30:00	2	1.742,81	343,65	0,00
1962,800	26.09.2007	07:35:00	16:25:00	16,42	36,17	0,45	0,55		27.09.2007	19:45:00	2	890,95	1.071,85	0,00

739,200	26.09.2007	08:15:00	15:45:00	15,75	22,33	0,71	0,29		27.09.2007	06:35:00	2	521,30	217,90	0,00
2086,467	27.09.2007	04:30:00	19:30:00	19,50	20,25	0,96	0,04		28.09.2007	00:45:00	2	2.009,19	77,28	0,00
1255,333	27.09.2007	23:55:00	00:05:00	0,08	39,92	0,00	0,60	0,40	29.09.2007	15:50:00	3	2,62	754,77	497,94
651,467	28.09.2007	08:25:00							28.09.2007	23:15:00	1	651,47	0,00	0,00
1082,200	28.09.2007	08:30:00	15:30:00	15,50	32,25	0,48	0,52		29.09.2007	16:45:00	2	520,13	562,07	0,00
1259,533	29.09.2007	16:15:00	07:45:00	7,75	29,25	0,26	0,74		30.09.2007	21:30:00	2	333,72	925,81	0,00
1397,200	29.09.2007	17:10:00	06:50:00	6,83	16,08	0,42	0,58		30.09.2007	09:15:00	2	593,63	803,57	0,00
1397,200	30.09.2007	09:30:00	14:30:00	14,50	21,58	0,67	0,33		01.10.2007	07:05:00	2	938,66	458,54	0,00
1305,733	30.09.2007	15:30:00	08:30:00	8,50	17,50	0,49	0,51		01.10.2007	09:00:00	2	634,21	671,52	0,00
2086,467	01.10.2007	10:25:00	13:35:00	13,58	19,92	0,68	0,32		02.10.2007	06:20:00	2	1.422,99	663,48	0,00
1255,333	01.10.2007	11:10:00	12:50:00	12,83	21,67	0,59	0,41		02.10.2007	08:50:00	2	743,54	511,79	0,00
1191,867	02.10.2007	06:50:00	17:10:00	17,17	17,50	0,98	0,02		03.10.2007	00:20:00	2	1.169,16	22,70	0,00
2086,467	02.10.2007	09:15:00	14:45:00	14,75	21,75	0,68	0,32		03.10.2007	07:00:00	2	1.414,96	671,51	0,00
11222,400	03.10.2007	05:00:00	19:00:00	19,00	36,50	0,52	0,48		04.10.2007	17:30:00	2	5.841,80	5.380,60	0,00
1397,200	03.10.2007	14:10:00	09:50:00	9,83	21,33	0,46	0,54		04.10.2007	11:30:00	2	644,02	753,18	0,00
2392,600	03.10.2007	19:45:00	04:15:00	4,25	24,92	0,17	0,83		04.10.2007	20:40:00	2	408,10	1.984,50	0,00
1136,333	04.10.2007	18:05:00	05:55:00	5,92	27,42	0,22	0,78		05.10.2007	21:30:00	2	245,23	891,11	0,00
4089,400	05.10.2007	01:00:00	23:00:00	23,00	39,92	0,58	0,42		06.10.2007	16:55:00	2	2.356,31	1.733,09	0,00
1962,800	05.10.2007	12:30:00	11:30:00	11,50	20,50	0,56	0,44		06.10.2007	09:00:00	2	1.101,08	861,72	0,00
739,200	06.10.2007	06:40:00							06.10.2007	17:25:00	1	739,20	0,00	0,00
2046,800	06.10.2007	10:30:00	13:30:00	13,50	14,75	0,92	0,08		07.10.2007	01:15:00	2	1.873,34	173,46	0,00
11924,267	06.10.2007	17:54:00	06:06:00	6,10	36,85	0,17	0,65	0,18	08.10.2007	06:45:00	3	1.973,89	7.766,14	2.184,23
2086,467	07.10.2007	01:45:00							07.10.2007	20:00:00	1	2.086,47	0,00	0,00
1305,733	07.10.2007	18:40:00	05:20:00	5,33	20,58	0,26	0,74		08.10.2007	15:15:00	2	338,33	967,41	0,00
28687,400	07.10.2007	22:57:00	01:03:00	1,05	26,85	0,04	0,89	0,07	09.10.2007	01:48:00	3	1.121,85	25.642,37	1.923,18
2104,200	08.10.2007	07:50:00	16:10:00	16,17	31,50	0,51	0,49		09.10.2007	15:20:00	2	1.079,93	1.024,27	0,00
2110,267	09.10.2007	02:45:00							09.10.2007	19:50:00	1	2.110,27	0,00	0,00
1392,067	09.10.2007	07:50:00	16:10:00	16,17	27,17	0,60	0,40		10.10.2007	11:00:00	2	828,41	563,66	0,00
1259,533	09.10.2007	15:55:00	08:05:00	8,08	26,33	0,31	0,69		10.10.2007	18:15:00	2	386,63	872,90	0,00
26740,467	09.10.2007	20:00:00	04:00:00	4,00	31,70	0,13	0,76	0,12	11.10.2007	03:42:00	3	3.374,19	20.245,15	3.121,13
1082,200	10.10.2007	08:15:00							10.10.2007	23:50:00	1	1.082,20	0,00	0,00
1191,867	10.10.2007	11:30:00	12:30:00	12,50	22,50	0,56	0,44		11.10.2007	09:30:00	2	662,15	529,72	0,00
295,400	10.10.2007	13:40:00	10:20:00	10,33	17,83	0,58	0,42		11.10.2007	07:30:00	2	171,17	124,23	0,00
1962,800	10.10.2007	18:30:00	05:30:00	5,50	22,50	0,24	0,76		11.10.2007	17:00:00	2	479,80	1.483,00	0,00

2392,600	11.10.2007	04:30:00							11.10.2007	21:30:00	1	2.392,60	0,00	0,00
1136,333	11.10.2007	20:50:00	03:10:00	3,17	18,00	0,18	0,82		12.10.2007	14:50:00	2	199,91	936,42	0,00
26294,800	11.10.2007	21:36:00	02:24:00	2,40	35,80	0,07	0,67	0,26	13.10.2007	09:24:00	3	1.762,78	17.627,80	6.904,22
	12.10.2007											0,00	0,00	0,00
2046,800	13.10.2007	22:05:00	01:55:00	1,92	19,00	0,10	0,90		14.10.2007	17:05:00	2	206,48	1.840,32	0,00
9275,000	14.10.2007	00:36:00							14.10.2007	23:36:00	1	9.275,00	0,00	0,00
	15.10.2007											0,00	0,00	0,00
1191,867	16.10.2007	09:25:00	14:35:00	14,58	22,42	0,65	0,35		17.10.2007	07:50:00	2	775,38	416,49	0,00
2086,467	16.10.2007	19:30:00	04:30:00	4,50	24,33	0,18	0,82		17.10.2007	19:50:00	2	385,85	1.700,61	0,00
1259,533	17.10.2007	18:00:00	06:00:00	6,00	25,25	0,24	0,76		18.10.2007	19:15:00	2	299,30	960,24	0,00
2392,600	17.10.2007	20:20:00	03:40:00	3,67	17,92	0,20	0,80		18.10.2007	14:15:00	2	489,65	1.902,95	0,00
	18.10.2007											0,00	0,00	0,00
1305,733	19.10.2007	19:40:00	04:20:00	4,33	19,08	0,23	0,77		20.10.2007	14:45:00	2	296,50	1.009,23	0,00
2099,533	20.10.2007	10:45:00	13:15:00	13,25	26,75	0,50	0,50		21.10.2007	13:30:00	2	1.039,96	1.059,58	0,00
1082,200	20.10.2007	15:05:00	08:55:00	8,92	29,25	0,30	0,70		21.10.2007	20:20:00	2	329,90	752,30	0,00
1962,800	20.10.2007	23:00:00	01:00:00	1,00	11,50	0,09	0,91		21.10.2007	10:30:00	2	170,68	1.792,12	0,00
3552,733	21.10.2007	11:45:00	12:15:00	12,25	21,42	0,57	0,43		22.10.2007	09:10:00	2	2.032,11	1.520,63	0,00
12235,067	21.10.2007	14:00:00	10:00:00	10,00	41,00	0,24	0,59	0,17	23.10.2007	07:00:00	3	2.984,16	7.161,99	2.088,91
1397,200	21.10.2007	21:20:00	02:40:00	2,67	21,83	0,12	0,88		22.10.2007	19:10:00	2	170,65	1.226,55	0,00
2086,467	22.10.2007	09:50:00	14:10:00	14,17	16,67	0,85	0,15		23.10.2007	02:30:00	2	1.773,50	312,97	0,00
2086,467	23.10.2007	03:10:00							23.10.2007	20:50:00	1	2.086,47	0,00	0,00
1191,867	23.10.2007	09:25:00	14:35:00	14,58	22,83	0,64	0,36		24.10.2007	08:15:00	2	761,23	430,64	0,00
12041,867	23.10.2007	17:12:00	06:48:00	6,80	45,13	0,15	0,53	0,32	25.10.2007	14:20:00	3	1.814,28	6.403,36	3.824,23
1151,267	24.10.2007	15:40:00	08:20:00	8,33	16,50	0,51	0,49		25.10.2007	08:10:00	2	581,45	569,82	0,00
2392,600	25.10.2007	16:50:00	07:10:00	7,17	19,17	0,37	0,63		26.10.2007	12:00:00	2	894,62	1.497,98	0,00
10338,533	26.10.2007	15:00:00	09:00:00	9,00	33,08	0,27	0,73	0,00	28.10.2007	00:05:00	3	2.812,50	7.499,99	26,04
651,467	26.10.2007	22:05:00	01:55:00	1,92	13,92	0,14	0,86		27.10.2007	12:00:00	2	89,72	561,74	0,00
1255,333	27.10.2007	15:15:00	08:45:00	8,75	25,08	0,35	0,65		28.10.2007	16:20:00	2	437,91	817,43	0,00
2086,467	28.10.2007	12:00:00	12:00:00	12,00	17,00	0,71	0,29		29.10.2007	05:00:00	2	1.472,80	613,67	0,00
1082,200	28.10.2007	18:15:00	05:45:00	5,75	23,08	0,25	0,75		29.10.2007	17:20:00	2	269,57	812,63	0,00
1305,733	29.10.2007	06:35:00	17:25:00	17,42	24,08	0,72	0,28		30.10.2007	06:40:00	2	944,28	361,45	0,00
1962,800	29.10.2007	10:50:00	13:10:00	13,17	42,67	0,31	0,56	0,13	31.10.2007	05:30:00	3	605,71	1.104,08	253,02
1191,867	30.10.2007	00:50:00	23:10:00	23,17	29,00	0,80	0,20		31.10.2007	05:50:00	2	952,12	239,74	0,00
2392,600	31.10.2007	16:20:00	07:40:00	7,67	18,67	0,41	0,59		01.11.2007	11:00:00	2	982,68	1.409,93	0,00

11844,933	31.10.2007	18:30:00	05:30:00	5,50	24,00	0,23	0,77		01.11.2007	18:30:00	2	2.714,46	9.130,47	0,00
1047,200	01.11.2007	11:20:00	12:40:00	12,67	25,42	0,50	0,50		02.11.2007	12:45:00	2	521,88	525,32	0,00
1151,267	01.11.2007	16:30:00	07:30:00	7,50	26,17	0,29	0,71		02.11.2007	18:40:00	2	329,98	821,29	0,00
1259,533	01.11.2007	17:05:00	06:55:00	6,92	41,17	0,17	0,58	0,25	03.11.2007	10:15:00	3	211,62	734,30	313,61
2086,467	02.11.2007	16:45:00	07:15:00	7,25	21,00	0,35	0,65		03.11.2007	13:45:00	2	720,33	1.366,14	0,00
1392,067	02.11.2007	17:15:00	06:45:00	6,75	38,25	0,18	0,63	0,20	04.11.2007	07:30:00	3	245,66	873,45	272,95
4089,400	03.11.2007	03:40:00	20:20:00	20,33	38,58	0,53	0,47		04.11.2007	18:15:00	2	2.155,10	1.934,30	0,00
1255,333	03.11.2007	16:20:00	07:40:00	7,67	38,75	0,20	0,62	0,18	05.11.2007	07:05:00	3	248,37	777,50	229,47
651,467	04.11.2007	07:00:00							04.11.2007	22:10:00	1	651,47	0,00	0,00
2086,467	04.11.2007	11:05:00	12:55:00	12,92	32,42	0,40	0,60		05.11.2007	19:30:00	2	831,37	1.255,10	0,00
11126,267	04.11.2007	19:38:00	04:22:00	4,37	41,87	0,10	0,57	0,32	06.11.2007	13:30:00	3	1.160,46	6.378,11	3.587,69
1305,733	05.11.2007	11:10:00	12:50:00	12,83	45,33	0,28	0,53	0,19	07.11.2007	08:30:00	3	369,64	691,27	244,83
2392,600	05.11.2007	20:00:00	04:00:00	4,00	36,25	0,11	0,66	0,23	07.11.2007	08:15:00	3	264,01	1.584,07	544,52
2099,533	06.11.2007	14:40:00	09:20:00	9,33	18,83	0,50	0,50		07.11.2007	09:30:00	2	1.040,48	1.059,06	0,00
1397,200	07.11.2007	08:50:00	15:10:00	15,17	22,25	0,68	0,32		08.11.2007	07:05:00	2	952,40	444,80	0,00
1191,867	08.11.2007	07:20:00							08.11.2007	23:00:00	1	1.191,87	0,00	0,00
	09.11.2007											0,00	0,00	0,00
1392,067	10.11.2007	01:05:00	22:55:00	22,92	28,83	0,79	0,21		11.11.2007	05:55:00	2	1.106,41	285,66	0,00
26035,333	10.11.2007	16:42:00	07:18:00	7,30	41,40	0,18	0,58	0,24	12.11.2007	10:06:00	3	4.590,77	15.092,95	6.351,62
	11.11.2007											0,00	0,00	0,00
1255,333	12.11.2007	11:10:00	12:50:00	12,83	24,25	0,53	0,47		13.11.2007	11:25:00	2	664,33	591,00	0,00
2406,600	12.11.2007	12:00:00	12:00:00	12,00	27,00	0,44	0,56		13.11.2007	15:00:00	2	1.069,60	1.337,00	0,00
	13.11.2007											0,00	0,00	0,00
2086,467	14.11.2007	07:10:00	16:50:00	16,83	26,83	0,63	0,37		15.11.2007	10:00:00	2	1.308,90	777,57	0,00
1191,867	14.11.2007	10:00:00	14:00:00	14,00	24,42	0,57	0,43		15.11.2007	10:25:00	2	683,39	508,48	0,00
1151,267	15.11.2007	10:45:00	13:15:00	13,25	29,75	0,45	0,55		16.11.2007	16:30:00	2	512,75	638,52	0,00
1305,733	15.11.2007	11:20:00	12:40:00	12,67	20,92	0,61	0,39		16.11.2007	08:15:00	2	790,72	515,01	0,00
10352,533	15.11.2007	23:30:00	00:30:00	0,50	30,00	0,02	0,80	0,18	17.11.2007	05:30:00	3	172,54	8.282,03	1.897,96
2046,800	16.11.2007	08:50:00	15:10:00	15,17	17,67	0,86	0,14		17.11.2007	02:30:00	2	1.757,16	289,64	0,00
2086,467	17.11.2007	02:35:00	21:25:00	21,42	26,83	0,80	0,20		18.11.2007	05:25:00	2	1.665,29	421,18	0,00
7029,867	17.11.2007	12:40:00	11:20:00	11,33	35,83	0,32	0,67	0,01	19.11.2007	00:30:00	3	2.223,40	4.708,38	98,09
1066,800	17.11.2007	14:20:00	09:40:00	9,67	25,42	0,38	0,62		18.11.2007	15:45:00	2	405,73	661,07	0,00
27041,933	18.11.2007	05:30:00	18:30:00	18,50	35,50	0,52	0,48		19.11.2007	17:00:00	2	14.092,28	12.949,66	0,00
651,467	18.11.2007	16:15:00	07:45:00	7,75	11,25	0,69	0,31		19.11.2007	03:30:00	2	448,79	202,68	0,00

1255,333	19.11.2007	08:10:00	15:50:00	15,83	25,83	0,61	0,39		20.11.2007	10:00:00	2	769,40	485,94	0,00
7941,733	19.11.2007	10:15:00	13:45:00	13,75	42,75	0,32	0,56	0,12	21.11.2007	05:00:00	3	2.554,36	4.458,52	928,86
1397,200	20.11.2007	10:40:00	13:20:00	13,33	27,17	0,49	0,51		21.11.2007	13:50:00	2	685,74	711,46	0,00
1191,867	21.11.2007	14:15:00	09:45:00	9,75	19,92	0,49	0,51		22.11.2007	10:10:00	2	583,47	608,40	0,00
2392,600	21.11.2007	17:20:00	06:40:00	6,67	29,67	0,22	0,78		22.11.2007	23:00:00	2	537,66	1.854,94	0,00
2086,467	21.11.2007	23:15:00	00:45:00	0,75	24,00	0,03	0,97		22.11.2007	23:15:00	2	65,20	2.021,26	0,00
1305,733	22.11.2007	23:30:00	00:30:00	0,50	20,50	0,02	0,98		23.11.2007	20:00:00	2	31,85	1.273,89	0,00
1151,267	23.11.2007	00:05:00	23:55:00	23,92	25,08	0,95	0,05		24.11.2007	01:10:00	2	1.097,72	53,55	0,00
11867,800	23.11.2007	20:36:00	03:24:00	3,40	34,67	0,10	0,69	0,21	25.11.2007	07:06:00	3	1.163,96	8.216,17	2.487,67
4089,400	24.11.2007	03:15:00	20:45:00	20,75	38,17	0,54	0,46		25.11.2007	17:25:00	2	2.223,28	1.866,12	0,00
1962,800	25.11.2007	16:25:00	07:35:00	7,58	38,58	0,20	0,62	0,18	27.11.2007	07:00:00	3	385,78	1.220,92	356,10
1397,200	25.11.2007	16:50:00	07:10:00	7,17	21,58	0,33	0,67		26.11.2007	14:25:00	2	463,94	933,26	0,00
27112,867	25.11.2007	22:00:00	02:00:00	2,00	24,00	0,08	0,92		26.11.2007	22:00:00	2	2.259,41	24.853,46	0,00
	26.11.2007											0,00	0,00	0,00
1082,200	27.11.2007	07:30:00	16:30:00	16,50	20,00	0,83	0,18		28.11.2007	03:30:00	2	892,82	189,39	0,00
14009,333	27.11.2007	13:55:00	10:05:00	10,08	45,83	0,22	0,52	0,26	29.11.2007	11:45:00	3	3.082,05	7.335,80	3.591,48
651,467	27.11.2007	20:45:00	03:15:00	3,25	12,92	0,25	0,75		28.11.2007	09:40:00	2	163,92	487,55	0,00
1191,867	28.11.2007	04:05:00	19:55:00	19,92	21,42	0,93	0,07		29.11.2007	01:30:00	2	1.108,39	83,48	0,00
2086,467	29.11.2007	02:00:00	22:00:00	22,00	23,50	0,94	0,06		30.11.2007	01:30:00	2	1.953,29	133,18	0,00
2392,600	29.11.2007	12:25:00	11:35:00	11,58	26,58	0,44	0,56		30.11.2007	15:00:00	2	1.042,54	1.350,06	0,00
739,200	29.11.2007	17:05:00	06:55:00	6,92	16,67	0,42	0,59		30.11.2007	09:45:00	2	306,77	432,43	0,00
2104,200	30.11.2007	04:30:00	19:30:00	19,50	20,75	0,94	0,06		01.12.2007	01:15:00	2	1.977,44	126,76	0,00
295,400	30.11.2007	10:15:00	13:45:00	13,75	21,25	0,65	0,35		01.12.2007	07:30:00	2	191,14	104,26	0,00
26715,733	01.12.2007	05:36:00	18:24:00	18,40	27,90	0,66	0,34		02.12.2007	09:30:00	2	17.618,98	9.096,76	0,00
1151,267	02.12.2007	08:10:00	15:50:00	15,83	56,25	0,28	0,43	0,29	04.12.2007	16:25:00	3	324,06	491,21	336,00
25610,667	02.12.2007	23:55:00	00:05:00	0,08	21,33	0,00	1,00		03.12.2007	21:15:00	2	100,04	25.510,63	0,00
10399,667	03.12.2007	22:06:00	01:54:00	1,90	42,73	0,04	0,56	0,39	05.12.2007	16:50:00	3	462,39	5.840,69	4.096,59
11696,067	04.12.2007	03:42:00	20:18:00	20,30	42,30	0,48	0,52		05.12.2007	22:00:00	2	5.613,01	6.083,06	0,00
1392,067	04.12.2007	16:45:00	07:15:00	7,25	38,92	0,19	0,62	0,20	06.12.2007	07:40:00	3	259,34	858,49	274,24
1962,800	05.12.2007	17:00:00	07:00:00	7,00	22,33	0,31	0,69		06.12.2007	15:20:00	2	615,21	1.347,59	0,00
2086,467	05.12.2007	22:45:00	01:15:00	1,25	22,50	0,06	0,94		06.12.2007	21:15:00	2	115,91	1.970,55	0,00
1191,867	06.12.2007	08:05:00	15:55:00	15,92	23,92	0,67	0,33		07.12.2007	08:00:00	2	793,19	398,67	0,00
1047,200	06.12.2007	08:55:00	15:05:00	15,08	37,00	0,41	0,59		07.12.2007	21:55:00	2	426,90	620,30	0,00
10875,200	06.12.2007	15:40:00	08:20:00	8,33	37,53	0,22	0,64	0,14	08.12.2007	05:12:00	3	2.414,56	6.953,95	1.506,69

1305,733	07.12.2007	00:10:00							07.12.2007	23:55:00	1	1.305,73	0,00	0,00
1255,333	08.12.2007	00:05:00							08.12.2007	20:00:00	1	1.255,33	0,00	0,00
739,200	09.12.2007	13:50:00	10:10:00	10,17	23,17	0,44	0,56		10.12.2007	13:00:00	2	324,40	414,80	0,00
7707,000	10.12.2007	00:12:00	23:48:00	23,80	38,30	0,62	0,38		11.12.2007	14:30:00	2	4.789,21	2.917,79	0,00
37598,867	10.12.2007	07:15:00	16:45:00	16,75	46,25	0,36	0,52	0,12	12.12.2007	05:30:00	3	13.616,89	19.510,76	4.471,22
1082,200	10.12.2007	13:35:00	10:25:00	10,42	24,67	0,42	0,58		11.12.2007	14:15:00	2	457,01	625,19	0,00
	11.12.2007											0,00	0,00	0,00
10908,333	12.12.2007	02:58:00	21:02:00	21,03	42,37	0,50	0,50		13.12.2007	21:20:00	2	5.415,55	5.492,79	0,00
2086,467	12.12.2007	13:45:00	10:15:00	10,25	21,25	0,48	0,52		13.12.2007	11:00:00	2	1.006,41	1.080,05	0,00
12041,867	13.12.2007	11:54:00	12:06:00	12,10	35,90	0,34	0,66		14.12.2007	23:48:00	2	4.058,68	7.983,19	0,00
1962,800	13.12.2007	22:30:00	01:30:00	1,50	28,50	0,05	0,84	0,11	15.12.2007	03:00:00	3	103,31	1.652,88	206,61
1191,867	14.12.2007	09:00:00	15:00:00	15,00	27,25	0,55	0,45		15.12.2007	12:15:00	2	656,07	535,79	0,00
37598,867	14.12.2007	23:25:00	00:35:00	0,58	31,33	0,02	0,77	0,22	16.12.2007	06:45:00	3	699,98	28.799,13	8.099,76
4089,400	15.12.2007	03:30:00	20:30:00	20,50	36,50	0,56	0,44		16.12.2007	16:00:00	2	2.296,79	1.792,61	0,00
2392,600	16.12.2007	11:20:00	12:40:00	12,67	39,92	0,32	0,60	0,08	18.12.2007	03:15:00	3	759,24	1.438,56	194,80
1397,200	16.12.2007	15:00:00	09:00:00	9,00	47,17	0,19	0,51	0,30	18.12.2007	14:10:00	3	266,60	710,94	419,65
1151,267	16.12.2007	15:35:00	08:25:00	8,42	40,00	0,21	0,60	0,19	18.12.2007	07:35:00	3	242,25	690,76	218,26
1339,333	16.12.2007	18:30:00	05:30:00	5,50	19,50	0,28	0,72		17.12.2007	14:00:00	2	377,76	961,57	0,00
1082,200	17.12.2007	23:30:00	00:30:00	0,50	24,08	0,02	0,98		18.12.2007	23:35:00	2	22,47	1.059,73	0,00
568,400	18.12.2007	12:30:00	11:30:00	11,50	28,50	0,40	0,60		19.12.2007	17:00:00	2	229,35	339,05	0,00
651,467	18.12.2007	13:30:00	10:30:00	10,50	14,08	0,75	0,25		19.12.2007	03:35:00	2	485,71	165,76	0,00
1305,733	19.12.2007	00:15:00	23:45:00	23,75	25,75	0,92	0,08		20.12.2007	02:00:00	2	1.204,32	101,42	0,00
8691,667	19.12.2007	15:50:00	08:10:00	8,17	29,17	0,28	0,72		20.12.2007	21:00:00	2	2.433,67	6.258,00	0,00
739,200	19.12.2007	17:20:00	06:40:00	6,67	18,92	0,35	0,65		20.12.2007	12:15:00	2	260,51	478,69	0,00
11252,267	20.12.2007	02:36:00	21:24:00	21,40	28,73	0,74	0,26		21.12.2007	07:20:00	2	8.380,46	2.871,81	0,00
1397,200	20.12.2007	12:35:00	11:25:00	11,42	19,33	0,59	0,41		21.12.2007	07:55:00	2	825,07	572,13	0,00
1962,800	21.12.2007	08:20:00	15:40:00	15,67	30,17	0,52	0,48		22.12.2007	14:30:00	2	1.019,35	943,45	0,00
2086,467	21.12.2007	10:10:00	13:50:00	13,83	25,50	0,54	0,46		22.12.2007	11:40:00	2	1.131,87	954,59	0,00
1191,867	21.12.2007	14:45:00	09:15:00	9,25	40,50	0,23	0,59	0,18	23.12.2007	07:15:00	3	272,22	706,29	213,36
1397,200	21.12.2007	15:35:00	08:25:00	8,42	40,25	0,21	0,60	0,19	23.12.2007	07:50:00	3	292,17	833,11	271,92
14014,933	22.12.2007	16:42:00	07:18:00	7,30	34,30	0,21	0,70	0,09	24.12.2007	03:00:00	3	2.982,77	9.806,37	1.225,80
1047,200	23.12.2007	15:15:00	08:45:00	8,75	25,25	0,35	0,65		24.12.2007	16:30:00	2	362,89	684,31	0,00
12041,867	24.12.2007	07:12:00	16:48:00	16,80	42,70	0,39	0,56	0,04	26.12.2007	01:54:00	3	4.737,78	6.768,26	535,82
2392,600	25.12.2007	00:10:00	23:50:00	23,83	31,67	0,75	0,25		26.12.2007	07:50:00	2	1.800,75	591,85	0,00

568,400	25.12.2007	15:30:00	08:30:00	8,50	16,75	0,51	0,49		26.12.2007	08:15:00	2	288,44	279,96	0,00
1082,200	25.12.2007	16:15:00	07:45:00	7,75	38,50	0,20	0,62	0,18	27.12.2007	06:45:00	3	217,85	674,62	189,74
2099,533	26.12.2007	02:20:00							26.12.2007	22:10:00	1	2.099,53	0,00	0,00
11903,267	27.12.2007	14:30:00	09:30:00	9,50	29,00	0,33	0,67		28.12.2007	19:30:00	2	3.899,35	8.003,92	0,00
739,200	28.12.2007	07:45:00	16:15:00	16,25	24,00	0,68	0,32		29.12.2007	07:45:00	2	500,50	238,70	0,00
24511,667	29.12.2007	02:00:00	22:00:00	22,00	33,50	0,66	0,34		30.12.2007	11:30:00	2	16.097,21	8.414,45	0,00
2392,600	29.12.2007	08:00:00	16:00:00	16,00	20,75	0,77	0,23		30.12.2007	04:45:00	2	1.844,90	547,70	0,00
1191,867	29.12.2007	15:30:00	08:30:00	8,50	21,25	0,40	0,60		30.12.2007	12:45:00	2	476,75	715,12	0,00
2046,800	30.12.2007	12:20:00	11:40:00	11,67	21,17	0,55	0,45		31.12.2007	09:30:00	2	1.128,16	918,64	0,00
1082,200	31.12.2007	05:05:00							31.12.2007	23:00:00	1	1.082,20	0,00	0,00

ANNEX VI

Summary of daily discharged ballast quantity

Arrival Time	Sum of 1st Day	Sum of 2nd Day	Sum of 3rd Day	Daily Ballast Quantity (m^3)
01.07.2007	2.064,64	762,90	0,00	2.064,64
02.07.2007	3.186,29	2.054,85	0,00	3.949,18
03.07.2007	1.168,68	1.310,72	0,00	3.223,53
04.07.2007	29.032,86	9.047,60	0,00	30.343,58
05.07.2007	8.564,18	19.294,43	8.253,92	17.611,79
06.07.2007	606,38	726,88	0,00	19.900,81
07.07.2007	6.176,20	9.059,53	0,00	15.157,01
08.07.2007	1.984,27	3.436,06	0,00	11.043,80
09.07.2007	5.272,78	9.286,75	0,00	8.708,85
10.07.2007	1.273,53	1.190,47	0,00	10.560,28
11.07.2007	436,58	995,15	0,00	1.627,06
12.07.2007	1.020,91	1.674,56	0,00	2.016,06
13.07.2007	2.649,22	2.614,78	0,00	4.323,78
14.07.2007	1.066,80	0,00	0,00	3.681,58
15.07.2007	11.378,88	2.980,92	0,00	11.378,88
16.07.2007	3.993,92	1.177,68	0,00	6.974,84
17.07.2007	2.441,20	443,48	295,65	3.618,88
18.07.2007	2.550,79	25.160,35	0,00	2.994,27
19.07.2007	10.990,94	5.520,66	0,00	36.446,94
20.07.2007	1.179,31	907,16	0,00	6.699,97
21.07.2007	7.042,67	10.076,53	0,00	7.949,83
22.07.2007	1.089,55	910,11	0,00	11.166,08
23.07.2007	1.526,27	780,46	0,00	2.436,39
24.07.2007	6.347,80	7.837,40	1.753,80	7.128,26
25.07.2007	148,27	176,07	0,00	7.985,67
26.07.2007	412,44	1.674,03	0,00	2.342,31
27.07.2007	1.975,74	1.246,59	0,00	3.649,77
28.07.2007	2.790,42	964,84	0,00	4.037,01
29.07.2007	1.939,03	2.439,70	0,00	2.903,88
30.07.2007	3.417,08	9.723,96	2.040,56	5.856,78
31.07.2007	0,00	0,00	0,00	9.723,96
01.08.2007	7.348,97	15.733,01	4.797,16	9.389,53
02.08.2007	1.077,11	1.328,09	0,00	16.810,12

03.08.2007	2.572,48	2.045,66	0,00	8.697,72
04.08.2007	1.452,54	3.488,52	0,00	3.498,20
05.08.2007	1.316,82	2.887,38	0,00	4.805,34
06.08.2007	2.493,01	650,46	0,00	5.380,39
07.08.2007	4.649,29	2.594,78	0,00	5.299,75
08.08.2007	2.737,60	701,27	0,00	5.332,38
09.08.2007	3.025,82	9.314,24	1.134,94	3.727,09
10.08.2007	1.597,08	502,45	0,00	10.911,32
11.08.2007	10.502,58	1.111,82	0,00	12.139,97
12.08.2007	8.056,26	8.324,67	0,00	9.168,08
13.08.2007	669,14	2.310,52	0,00	8.993,81
14.08.2007	3.128,00	3.681,60	0,00	5.438,52
15.08.2007	921,54	125,66	0,00	4.603,14
16.08.2007	27.173,71	1.803,49	0,00	27.299,37
17.08.2007	1.686,98	10.170,09	0,00	3.490,47
18.08.2007	2.877,36	4.503,44	0,00	13.047,45
19.08.2007	2.888,20	7.324,41	1.686,45	7.391,64
20.08.2007	4.617,03	7.177,42	147,08	11.941,44
21.08.2007	3.172,71	1.221,79	82,23	12.036,59
22.08.2007	186,07	1.860,73	0,00	1.554,94
23.08.2007	1.148,80	1.088,40	0,00	3.091,76
24.08.2007	12.010,95	14.740,71	0,00	13.099,35
25.08.2007	1.906,47	10.663,74	993,93	16.647,18
26.08.2007	941,99	1.185,08	0,00	11.605,72
27.08.2007	9.472,07	9.604,33	0,00	11.651,08
28.08.2007	158,16	1.033,70	0,00	9.762,49
29.08.2007	5.154,40	16.079,87	0,00	6.188,10
30.08.2007	2.309,23	7.085,48	1.067,49	18.389,10
31.08.2007	821,15	2.105,88	432,97	7.906,64
01.09.2007	2.628,75	1.136,79	0,00	5.802,11
02.09.2007	3.891,09	852,11	0,00	5.460,85
03.09.2007	15.654,90	849,70	0,00	16.507,01
04.09.2007	4.380,12	12.186,19	43,29	5.229,82
05.09.2007	1.377,85	667,08	0,00	13.564,04
06.09.2007	3.121,24	7.752,56	3.081,87	3.831,61
07.09.2007	938,12	1.108,68	0,00	8.690,68
08.09.2007	9.208,04	13.615,33	243,97	13.398,59
09.09.2007	1.359,18	1.919,15	0,00	14.974,51

10.09.2007	1.983,26	960,94	0,00	4.146,38
11.09.2007	4.407,65	7.604,35	0,00	5.368,59
12.09.2007	2.256,39	1.482,54	0,00	9.860,74
13.09.2007	763,54	935,13	0,00	2.246,08
14.09.2007	0,00	0,00	0,00	935,13
15.09.2007	2.478,46	799,87	0,00	2.478,46
16.09.2007	2.855,86	1.327,34	0,00	3.655,73
17.09.2007	1.351,09	2.643,17	68,07	2.678,43
18.09.2007	12.368,40	14.347,34	0,00	15.011,56
19.09.2007	1.507,63	313,77	0,00	15.923,04
20.09.2007	2.451,87	894,13	0,00	2.765,65
21.09.2007	6.006,35	6.111,11	0,00	6.900,48
22.09.2007	1.294,96	2.188,71	0,00	7.406,07
23.09.2007	2.018,88	11.506,14	2.535,31	4.207,59
24.09.2007	660,38	272,49	0,00	12.166,52
25.09.2007	3.765,89	1.576,98	0,00	6.573,69
26.09.2007	3.155,06	1.633,40	0,00	4.732,04
27.09.2007	2.011,81	832,05	497,94	3.645,21
28.09.2007	1.171,59	562,07	0,00	2.003,64
29.09.2007	927,35	1.729,38	0,00	1.987,36
30.09.2007	1.572,87	1.130,06	0,00	3.302,25
01.10.2007	2.166,53	1.175,27	0,00	3.296,59
02.10.2007	2.584,12	694,21	0,00	3.759,39
03.10.2007	6.893,92	8.118,28	0,00	7.588,13
04.10.2007	245,23	891,11	0,00	8.363,51
05.10.2007	3.457,40	2.594,80	0,00	4.348,50
06.10.2007	4.586,44	7.939,60	2.184,23	7.181,24
07.10.2007	3.546,65	26.609,77	1.923,18	11.486,25
08.10.2007	1.079,93	1.024,27	0,00	29.873,94
09.10.2007	6.699,49	21.681,71	3.121,13	9.646,94
10.10.2007	2.395,31	2.136,96	0,00	24.077,02
11.10.2007	4.355,29	18.564,22	6.904,22	9.613,37
12.10.2007	0,00	0,00	0,00	18.564,22
13.10.2007	206,48	1.840,32	0,00	7.110,70
14.10.2007	9.275,00	0,00	0,00	11.115,32
15.10.2007	0,00			0,00
16.10.2007	1.161,23	2.117,10	0,00	1.161,23
17.10.2007	788,94	2.863,19	0,00	2.906,05

18.10.2007	0,00	0,00	0,00	2.863,19
19.10.2007	296,50	1.009,23	0,00	296,50
20.10.2007	1.540,54	3.604,00	0,00	2.549,77
21.10.2007	5.186,92	9.909,17	2.088,91	8.790,92
22.10.2007	1.773,50	312,97	0,00	11.682,66
23.10.2007	4.661,98	6.833,99	3.824,23	7.063,86
24.10.2007	581,45	569,82	0,00	7.415,44
25.10.2007	894,62	1.497,98	0,00	5.288,67
26.10.2007	2.902,22	8.061,74	26,04	4.400,20
27.10.2007	437,91	817,43	0,00	8.499,64
28.10.2007	1.742,37	1.426,29	0,00	2.585,84
29.10.2007	1.549,99	1.465,52	253,02	2.976,29
30.10.2007	952,12	239,74	0,00	2.417,65
31.10.2007	3.697,14	10.540,39	0,00	4.189,90
01.11.2007	1.063,49	2.080,91	313,61	11.603,88
02.11.2007	965,99	2.239,59	272,95	3.046,89
03.11.2007	2.403,47	2.711,79	229,47	4.956,67
04.11.2007	2.643,30	7.633,21	3.587,69	5.628,04
05.11.2007	633,65	2.275,34	789,35	8.496,33
06.11.2007	1.040,48	1.059,06	0,00	6.903,50
07.11.2007	952,40	444,80	0,00	2.800,80
08.11.2007	1.191,87	0,00	0,00	1.636,67
09.11.2007	0,00	0,00	0,00	0,00
10.11.2007	5.697,18	15.378,60	6.351,62	5.697,18
11.11.2007	0,00	0,00	0,00	15.378,60
12.11.2007	1.733,93	1.928,00	0,00	8.085,55
13.11.2007	0,00	0,00	0,00	1.928,00
14.11.2007	1.992,29	1.286,04	0,00	1.992,29
15.11.2007	1.476,01	9.435,55	1.897,96	2.762,05
16.11.2007	1.757,16	289,64	0,00	11.192,71
17.11.2007	4.294,42	5.790,62	98,09	6.482,02
18.11.2007	14.541,06	13.152,34	0,00	20.331,69
19.11.2007	3.323,76	4.944,45	928,86	16.574,18
20.11.2007	685,74	711,46	0,00	5.630,19
21.11.2007	1.186,33	4.484,60	0,00	2.826,65
22.11.2007	31,85	1.273,89	0,00	4.516,45
23.11.2007	2.261,68	8.269,72	2.487,67	3.535,56
24.11.2007	2.223,28	1.866,12	0,00	10.492,99

25.11.2007	3.109,12	27.007,65	356,10	7.462,91
26.11.2007	0,00	0,00	0,00	27.007,65
27.11.2007	4.138,79	8.012,73	3.591,48	4.494,89
28.11.2007	1.108,39	83,48	0,00	9.121,12
29.11.2007	3.302,60	1.915,67	0,00	6.977,56
30.11.2007	2.168,58	231,02	0,00	4.084,25
01.12.2007	17.618,98	9.096,76	0,00	17.850,00
02.12.2007	424,10	26.001,83	336,00	9.520,86
03.12.2007	462,39	5.840,69	4.096,59	26.464,22
04.12.2007	5.872,34	6.941,55	274,24	12.049,03
05.12.2007	731,12	3.318,15	0,00	11.769,26
06.12.2007	3.634,66	7.972,92	1.506,69	7.227,04
07.12.2007	1.305,73	0,00	0,00	9.278,65
08.12.2007	1.255,33	0,00	0,00	2.762,02
09.12.2007	324,40	414,80	0,00	324,40
10.12.2007	18.863,10	23.053,75	4.471,22	19.277,91
11.12.2007	0,00	0,00	0,00	23.053,75
12.12.2007	6.421,96	6.572,84	0,00	10.893,18
13.12.2007	4.161,98	9.636,07	206,61	10.734,83
14.12.2007	1.356,05	29.334,93	8.099,76	10.992,12
15.12.2007	2.296,79	1.792,61	0,00	31.838,32
16.12.2007	1.645,85	3.801,83	832,72	11.538,22
17.12.2007	22,47	1.059,73	0,00	3.824,30
18.12.2007	715,06	504,80	0,00	2.607,51
19.12.2007	3.898,49	6.838,11	0,00	4.403,30
20.12.2007	9.205,53	3.443,94	0,00	16.043,63
21.12.2007	2.715,61	3.437,44	485,28	6.159,55
22.12.2007	2.982,77	9.806,37	1.225,80	6.420,21
23.12.2007	362,89	684,31	0,00	10.654,54
24.12.2007	4.737,78	6.768,26	535,82	6.647,89
25.12.2007	2.307,03	1.546,43	189,74	9.075,30
26.12.2007	2.099,53	0,00	0,00	4.181,78
27.12.2007	3.899,35	8.003,92	0,00	4.089,08
28.12.2007	500,50	238,70	0,00	8.504,42
29.12.2007	18.418,86	9.677,28	0,00	18.657,56
30.12.2007	1.128,16	918,64	0,00	10.805,43
31.12.2007	1082,2	0	0	2.000,84

ANNEX VII

Fitting results of discharging ballast water data

#	Distribution	Parameters
1	Beta	α_1=1,037 α_2=3,5123 a=-1,1864E-14 b=36447,0
2	Cauchy	σ=3147,6 μ=6122,8
3	Chi-Squared	ν=10147
4	Chi-Squared	ν=8394
5	Erlang	m=2 β=4407,0
6	Erlang	m=1 β=5098,2
7	Error Function	h=1,0809E-4
8	Exponential	λ=1,1912E-4
9	Exponential (2P)	λ=1,1912E-4 γ=-1,0000E-14
10	Fatigue Life	α=0,88824 β=6328,6
11	Fatigue Life	α=0,88824 β=6328,6
12	Frechet	α=1,0535 β=4230,2
13	Frechet	α=0,65259 β=2356,8
14	Gamma	α=1,9258 β=4407,0
15	Gamma	α=1,6466 β=5098,2
16	Gen. Extreme Value	k=0,17738 σ=4011,2 μ=5234,6
17	Gen. Pareto	k=-0,10288 σ=7820,4 μ=1304,1
18	Gumbel Max	σ=5100,8 μ=5450,6
19	Gumbel Min	σ=5100,8 μ=11339,0
20	Inv. Gaussian	λ=8902,4 μ=8487,2
21	Inv. Gaussian	λ=13824,0 μ=8394,9
22	Johnson SB	γ=2,1116 δ=0,99611 λ=55540,0 ξ=492,01
23	Laplace	λ=2,1617E-4 μ=8394,9
24	Log-Logistic	α=0,88779 β=5429,7
25	Log-Logistic	α=2,23 β=6566,6

26	Logistic	σ=3606,8 μ=8394,9
27	Lognormal	σ=0,79459 μ=8,7648
28	Lognormal	σ=0,7946 μ=8,7648
29	Normal	σ=6542,1 μ=8394,9
30	Pert	m=3480,7 a=-1,2000E-14 b=36447,0
31	Power Function	α=0,47073 a=4,6132E-15 b=36529,0
32	Rayleigh	σ=7559,2
33	Rayleigh	σ=6698,2
34	Student's t	ν=2
35	Triangular	m=-1,0000E-14 a=-1,0000E-14 b=36447,0
36	Uniform	a=-2936,3 b=19726,0
37	Weibull	α=0,57961 β=13975,0
38	Weibull	α=1,4061 β=9372,9
39	Johnson SU	No fit
40	Pareto	No fit

ANNEX VIII

Calculation details of loading ballast quantities

Ballast Capacity of Vessels (m^3)	Arrival Date (day)	Arrival Time (h)	Midnight - Arrival Time (h)	Midnight - Arrival Time (metric)	Departure Date (day)	Departure Time (h)	Midnight-Departure Time (h)	Midnight-Departure Time (metric)	1st day rate	2nd day rate	3rd day rate	4th day rate	Operation Days	1st day (m^3)	2nd day (m^3)	3rd day (m^3)	4th day (m^3)	Daily Ballast (m^3)
24343.2	04/07/2007	07:30:00	23.6875	16.5	05/07/2007	21:00:00	23.125	3	0.85	0.154			2	20598	3745.1			20598,09
			24	0			24	0					1	0				3745,108
			24	0			24	0					1	0				0
39422.133	07/07/2007	19:12:00	23.2	4.8	08/07/2007	22:00:00	23.0833333	2	0.71	0.294			2	27827	11595			27827,39
			24	0			24	0					1	0				11594,75
23338	09/07/2007	19:10:00	23.201389	4.8333333	11/07/2007	00:24:00	23.9833333	23.6	0.09	0.458	0.45		3	2151.3	10682	10504		2151,31
			24	0			24	0					1	0				10682,36
			24	0			24	0					1	0				10504,33
			24	0			24	0					1	0				0
10710	13/07/2007	13:00:00	23.458333	11	14/07/2007	15:40:00	23.3472222	8.33333333	0.57	0.431			2	6093.6	4616.4			6093,621
			24	0			24	0					1	0				4616,379
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
24084.667	19/07/2007	11:30:00	23.520833	12.5	20/07/2007	18:15:00	23.2395833	5.75	0.68	0.315			2	16496	7588.3			16496,35
39422.133	20/07/2007	20:12:00	23.158333	3.8	22/07/2007	01:30:00	23.9375	22.5	0.08	0.477	0.447		3	2978.2	18810	17634		10566,53
			24	0			24	0					1	0				18809,77
			24	0			24	0					1	0				17634,16
			24	0			24	0					1	0				0
38023.533	24/07/2007	22:45:00	23.052083	1.25	26/07/2007	05:05:00	23.7881944	18.9166667	0.03	0.543	0.428		3	1076.1	20662	16286		1076,138
			24	0			24	0					1	0				20661,84
			24	0			24	0					1	0				16285,55
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
39427.733	31/07/2007	09:24:00	23.608333	14.6	01/08/2007	17:30:00	23.2708333	6.5	0.69	0.308			2	27282	12146			27281,75
			24	0			24	0					1	0				12145,98
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0

			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
38023.533	08/08/2007	15:36:00	23.35	8.4	09/08/2007	20:00:00	23.1666667	4	0.68	0.323			2	25758	12266			25757,88
			24	0			24	0					1	0				12265,66
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
38023.533	15/08/2007	02:24:00	23.9	21.6	16/08/2007	05:00:00	23.7916667	19	0.53	0.468			2	20229	17794			20229,27
			24	0			24	0					1	0				17794,26
			24	0			24	0					1	0				0
10710	18/08/2007	21:06:00	23.120833	2.9	21/08/2007	05:30:00	23.7708333	18.5	0.04	0.346	0.346	0.267	4	447.54	3703.7	3703.7	2855	447,536
			24	0			24	0					1	0				3703,746
			24	0			24	0					1	0				3703,746
26644.333	21/08/2007	19:45:00	23.177083	4.25	23/08/2007	01:15:00	23.9479167	22.75	0.08	0.471	0.446		3	2220.4	12539	11885		5075,332
			24	0			24	0					1	0				12538,51
			24	0			24	0					1	0				11885,46
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
39429.133	27/08/2007	02:25:00	23.899306	21.583333	28/08/2007	14:10:00	23.4097222	9.83333333	0.69	0.313			2	27088	12341			27087,92
			24	0			24	0					1	0				12341,21
24253.6	29/08/2007	20:10:00	23.159722	3.8333333	30/08/2007	19:54:00	23.1708333	4.1	0.48	0.517			2	11719	12534			11719,18
			24	0			24	0					1	0				12534,42
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
10710	03/09/2007	09:24:00	23.608333	14.6	04/09/2007	08:15:00	23.65625	15.75	0.48	0.519			2	5152.1	5557.9			5152,092
39427.733	04/09/2007	11:00:00	23.541667	13	05/09/2007	16:45:00	23.3020833	7.25	0.64	0.358			2	25312	14116			30869,54
			24	0			24	0					1	0				14116,1
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
17679.2	11/09/2007	00:10:00	23.993056	23.833333	12/09/2007	08:42:00	23.6375	15.3	0.61	0.391			2	10767	6912.1			10767,14
			24	0			24	0					1	0				6912,055
			24	0			24	0					1	0				0

39427.733	14/09/2007	17:24:00	23.275	6.6	15/09/2007	21:00:00	23.125	3	0.69	0.313			2	27107	12321			27106,57
			24	0			24	0					1	0				12321,17
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
19605.133	18/09/2007	03:45:00	23.84375	20.25	19/09/2007	05:00:00	23.7916667	19	0.52	0.484			2	10115	9490.4			10114,75
39422.133	19/09/2007	11:12:00	23.533333	12.8	20/09/2007	23:45:00	23.0104167	0.25	0.98	0.019			2	38667	755.21			48157,3
			24	0			24	0					1	0				755,2133
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
26679.8	23/09/2007	10:00:00	23.583333	14	24/09/2007	11:10:00	23.5347222	12.8333333	0.52	0.478			2	13920	12760			13919,9
27099.333	24/09/2007	13:30:00	23.4375	10.5	25/09/2007	10:00:00	23.5833333	14	0.43	0.571			2	11614	15485			24373,9
			24	0			24	0					1	0				15485,33
			24	0			24	0					1	0				0
39427.733	27/09/2007	14:24:00	23.4	9.6	28/09/2007	19:40:00	23.1805556	4.33333333	0.69	0.311			2	27166	12262			27165,52
			24	0			24	0					1	0				12262,21
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
41508.133	02/10/2007	23:54:00	23.004167	0.1	04/10/2007	09:42:00	23.5958333	14.3	0	0.625	0.372		3	108.09	25943	15457		108,0941
			24	0			24	0					1	0				25942,58
			24	0			24	0					1	0				15457,46
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
41974.8	09/10/2007	07:36:00	23.683333	16.4	10/10/2007	20:08:00	23.1611111	3.86666667	0.81	0.191			2	33966	8008.4			33966,45
			24	0			24	0					1	0				8008,35
			24	0			24	0					1	0				0
17679.2	12/10/2007	06:05:00	23.746528	17.916667	13/10/2007	10:05:00	23.5798611	13.9166667	0.56	0.437			2	9950.3	7728.9			9950,335
			24	0			24	0					1	0				7728,865
			24	0			24	0					1	0				0
41974.8	15/10/2007	18:48:00	23.216667	5.2	17/10/2007	06:30:00	23.7291667	17.5	0.11	0.514	0.375		3	4673.9	21572	15729		4673,854
			24	0			24	0					1	0				21571,63
10710	17/10/2007	14:12:00	23.408333	9.8	18/10/2007	19:45:00	23.1770833	4.25	0.7	0.302			2	7470.3	3239.7			23199,64
			24	0			24	0					1	0				3239,68
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
39422.133	23/10/2007	15:45:00	23.34375	8.25	25/10/2007	14:50:00	23.3819444	9.16666667	0.2	0.579	0.221		3	7852.7	22844	8725.2		7852,699
			24	0			24	0					1	0				22844,21

10710	25/10/2007	16:35:00	23.309028	7.4166667	28/10/2007	08:06:00	23.6625	15.9	0.1	0.337	0.337	0.223	4	1113.8	3604.2	3604.2	2388	9839,021
			24	0			24	0					1	0				3604,207
			24	0			24	0					1	0				3604,207
10845.333	28/10/2007	21:42:00	23.095833	2.3	29/10/2007	19:42:00	23.1791667	4.3	0.35	0.652			2	3779.4	7065.9			6167,221
			24	0			24	0					1	0				7065,899
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
41508.133	01/11/2007	07:42:00	23.679167	16.3	02/11/2007	14:00:00	23.4166667	10	0.62	0.38			2	25726	15783			25725,57
10216.733	02/11/2007	16:30:00	23.3125	7.5	03/11/2007	23:15:00	23.03125	0.75	0.91	0.091			2	9287.9	928.79			25070,5
			24	0			24	0					1	0				928,7939
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
41974.8	07/11/2007	08:12:00	23.658333	15.8	08/11/2007	13:30:00	23.4375	10.5	0.6	0.399			2	25217	16758			25216,8
			24	0			24	0					1	0				16758
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
10710	14/11/2007	17:24:00	23.275	6.6	15/11/2007	20:35:00	23.1423611	3.41666667	0.66	0.341			2	7056.8	3653.2			7056,839
			24	0			24	0					1	0				3653,161
			24	0			24	0					1	0				0
37120.533	17/11/2007	11:24:00	23.525	12.6	18/11/2007	22:00:00	23.0833333	2	0.86	0.137			2	32036	5085			32035,53
12718.533	18/11/2007	23:54:00	23.004167	0.1	20/11/2007	03:00:00	23.875	21	0	0.532	0.466		3	28.201	6768.2	5922.2		5113,205
			24	0			24	0					1	0				6768,177
			24	0			24	0					1	0				5922,155
10710	21/11/2007	17:12:00	23.283333	6.8	22/11/2007	21:00:00	23.125	3	0.69	0.306			2	7431.4	3278.6			7431,429
			24	0			24	0					1	0				3278,571
38023.533	23/11/2007	23:54:00	23.004167	0.1	25/11/2007	11:12:00	23.5333333	12.8	0	0.65	0.347		3	103.04	24731	13190		103,0448
			24	0			24	0					1	0				24730,75
			24	0			24	0					1	0				13189,74
19331.2	26/11/2007	04:00:00	23.833333	20	27/11/2007	10:30:00	23.5625	13.5	0.6	0.403			2	11541	7790.2			11541,01
			24	0			24	0					1	0				7790,185
41508.133	28/11/2007	07:48:00	23.675	16.2	29/11/2007	21:00:00	23.125	3	0.84	0.156			2	35022	6485.6			35022,49
			24	0			24	0					1	0				6485,646
19130.067	30/11/2007	01:48:00	23.925	22.2	01/12/2007	20:30:00	23.1458333	3.5	0.86	0.136			2	16525	2605.3			16524,8
			24	0			24	0					1	0				2605,262
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
41508.133	04/12/2007	12:18:00	23.4875	11.7	06/12/2007	00:10:00	23.9930556	23.8333333	0.2	0.403	0.4		3	8157.5	16733	16617		8157,533

			24	0			24	0					1	0				16733,4
10710	06/12/2007	10:54:00	23.545833	13.1	07/12/2007	15:15:00	23.3645833	8.75	0.6	0.4			2	6421.1	4288.9			23038,3
19525.8	07/12/2007	17:20:00	23.277778	6.6666667	09/12/2007	03:48:00	23.8416667	20.2	0.13	0.472	0.397		3	2559.1	9212.7	7754		6847,984
			24	0			24	0					1	0				9212,697
			24	0			24	0					1	0				7754,02
			24	0			24	0					1	0				0
39422.133	11/12/2007	13:00:00	23.458333	11	12/12/2007	19:45:00	23.1770833	4.25	0.72	0.279			2	28436	10986			28435,64
			24	0			24	0					1	0				10986,5
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
11844.933	15/12/2007	12:06:00	23.495833	11.9	16/12/2007	23:36:00	23.0166667	0.4	0.97	0.033			2	11460	385.2			11459,73
			24	0			24	0					1	0				385,2011
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
			24	0			24	0					1	0				0
39422.133	20/12/2007	10:00:00	23.583333	14	21/12/2007	18:15:00	23.2395833	5.75	0.71	0.291			2	27945	11477			27944,8
			24	0			24	0					1	0				11477,33
			24	0			24	0					1	0				0
11970.467	23/12/2007	00:48:00	23.966667	23.2	23/12/2007	21:48:00	23.0916667	2.2					1	11970				11970,47
41508.133	24/12/2007	23:42:00	23.0125	0.3	26/12/2007	04:12:00	23.825	19.8	0.01	0.544	0.449		3	282.37	22589	18636		282,3683
			24	0			24	0					1	0				22589,46
10710	26/12/2007	20:00:00	23.166667	4	28/12/2007	02:00:00	23.9166667	22	0.08	0.48	0.44		3	856.8	5140.8	4712.4		19493,1

ANNEX IX

Fitting results of loading ballast water data

#	**Distribution**	**Parameters**
1	Beta	α_1=0,07041 α_2=4,9113 a=5,0719E-15 b=49839,0
2	Cauchy	σ=3558,0 μ=1568,0
3	Chi-Squared	ν=9804
4	Chi-Squared	ν=7863
5	Error Function	h=7,1852E-5
6	Exponential	λ=1,2717E-4
7	Exponential (2P)	λ=1,2717E-4 γ=-1,0000E-14
8	Fatigue Life	α=1,2878 β=7950,9
9	Fatigue Life	α=1,2878 β=7950,9
10	Frechet	α=0,6302 β=4621,3
11	Frechet	α=0,16497 β=1,8508
12	Gamma	α=1,3851 β=9624,1
13	Gamma	α=0,63849 β=12316,0
14	Gen. Extreme Value	k=0,29158 σ=5150,4 μ=2831,0
15	Gen. Pareto	k=0,08372 σ=8925,9 μ=-1877,8
16	Gumbel Max	σ=7673,2 μ=3434,6
17	Gumbel Min	σ=7673,2 μ=12293,0
18	Inv. Gaussian	λ=3132,2 μ=13331,0
19	Inv. Gaussian	λ=5020,9 μ=7863,7
20	Johnson SB	γ=1,2763 δ=0,73939 λ=51505,0 ξ=-3138,6
21	Laplace	λ=1,4370E-4 μ=7863,7
22	Log-Logistic	α=1,7516 β=10411,0
23	Log-Logistic	α=0,14786 β=2,3586
24	Logistic	σ=5425,7 μ=7863,7
25	Lognormal	σ=1,1498 μ=9,0953

26	Lognormal	σ=1,1499 μ=9,0953
27	Normal	σ=9841,2 μ=7863,7
28	Power Function	α=0,03704 a=4,5039E-15 b=71010,0
29	Rayleigh	σ=6274,3
30	Rayleigh	σ=11578,0
31	Student's t	ν=2
32	Uniform	a=-9181,8 b=24909,0
33	Weibull	α=0,0416 β=5,9699
34	Weibull	α=1,3074 β=14349,0
35	Erlang	No fit
36	Erlang (3P)	No fit
37	Johnson SU	No fit
38	Pareto	No fit
39	Pert	No fit
40	Triangular	No fit