Oceanographic and Environmental Impact of Operation of Lng Ships: A Review

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Abstract- *Humans have always had a close relationship with the aquatic environment, including the early use of the sea for food harvesting and communication. Today, the sea is an important component of the transportation system, with large amounts of cargo and passengers. This chapter provides a short introduction to ships and shipping, focussing primarily on commercial ships; nonetheless, many of the emissions, impacts and measures discussed throughout this book are common to other sectors, such as leisure, research and fishing. This chapter also introduces the environmental impacts related to ship operations. Ship transportation has increased tremendously since the industrial revolution, which has resulted in increased emissions due to shipping and increased stresses on the environment.*

However, this trend is not only related to shipping. Currently, there are several warning signs that we are not taking care of the Earth and its ecosystem in a sustainable manner, that the Earth's ecosystems are degrading and that natural capital is being exploited, e.g., by the burning of fossil fuels. The marine industry is a component of our society; similar to all industry sectors, it contributes to unsustainable patterns in our society. Although the marine industry is a contributor to these problems, it can also be part of the solution, yet several challenges must be addressed. Sustainability and related concepts, such as ecosystem services, planetary boundaries and resilience thinking, could be used as guidance in addressing these challenges.

Humans have always had a close relationship with the aquatic environment. Indeed,a scientific discussion debates whether the first humans evolved in a dry land environment, on the savannah, or in shallow water environments (as the "water man" or "aquatic ape"). With respect to environmental awareness, the sea has come into focus relatively late compared with other natural areas. Independent of this observation, the sea has served as an important transportation route and a source of food and recreation throughout history. In a world where more than 70 % of the surface is covered by oceans, our interaction with and dependence on the sea in numerous aspects is obvious.

Keywords- Sustainable, Venting, Ballast, IMO, MARPOL

I. INTRODUCTION

In today's high developing world, globalisation has become rather a need, than a demand. Ranging from a toothbrush to the mobile phones, all are result of rapid encompassing of globalisation, resulting in a higher growth of international trade and a strong economy. Coming back to the international trade, 90% of it is carried out through gigantic ships over the vast oceans to almost all of the coastal countries. Though the maritime industry has eased the transportation, it also poses some severe threat to the environment and the ecosystem, given their size and the vulnerability of the sea through which they steer.

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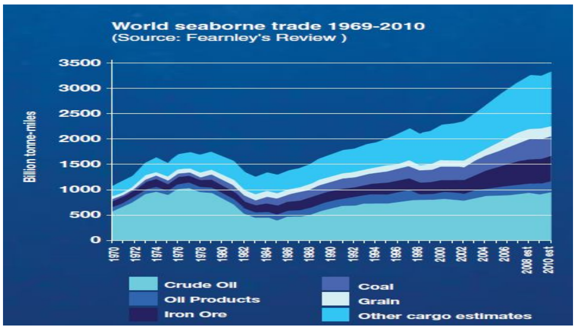
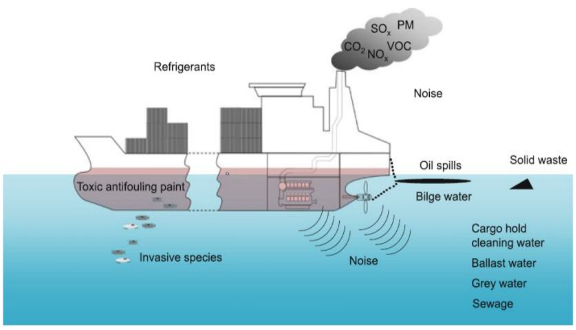


In this paper, I would discuss some of the serious threats they pose, and the measures implemented for the mitigation and recovery from a marine pollution incident, which I learnt while had a chance to undergo familiarisation and basic training on the world's largest LNG carrier- 'AAMIRA', under command of Captain Branko Maric.

A ship is like a small floating island, or a small township, with sizes up to 400 metres and above, with all the basic necessities and facilities as required to run a township and more. Given its complex operation, the pollution threat categories can be briefly summarised as under, which would be discussed in brief later in this presentation.

Operations related:

- Pollution due to oil and oily wastes/residues
- Emission of SOx and NOx
- General operational waste including paper, plastic ,glass, dunnage etc
- Food waste
- Sewage
- Pathogens induced by ballast water



Environmental impacts of marine transportation during the use of a vessel

For thousands of years, all shipboard waste and garbage, including waste oil was thrown over the side in the ocean, which resulted in the disturbance to the ecological system and a devastating effect on the marine life.

There is more and more marine traffic, and a lot of additional garbage is made up of disposable, man-made material; some of it designed to be used only once before being discarded, consequentially, the resultant garbage quantity to be discharged at sea, getting literally out of control.

Every year, the oceans, seas and beaches are getting dirtier and more polluted, thousands of seals get tangled up in discarded nets, countless sea birds die as a result of eating garbage containing plastic material.

Environmental concerns and Responses

In 1973, IMO adapted the International Convention for prevention of Pollution from ships, now universally known as the MARPOL, amended by Protocols adopted in 1978 and 1997.MARPOL specifically addresses various categories of pollution caused by operation of ships, including oil pollution, noxious substances, sewage, garbage and air pollution.

MARPOL has greatly contributed to a significant decrease in pollution from international shipping and applies to 99% of the world's merchant shipping tonnage.

Other conventions also address anti-fouling systems used on ship's hull, transfer of invasive aquatic species by ships' ballast water and its environmentally sound recycling of ships.

Sustainability and Sustainable Development

Sustainable development is a global goal that gained international attention due to the Report of the World Commission on Environment and Development in 1987, which is also known as the Brundtland Report . This concept is related to a series of normative ideas that include protecting the environment, promoting human welfare (especially the urgent development needs of the poor), concern for the well-being of future generations, and public participation in environment and development decision-making. However, sustainable development and sustainability are terms that lack consensus and suffer from a variety of different and vague definition]. Key questions for a relevant definition are provided below:

• What is intended for sustainability?

– Nature (earth, biodiversity and ecosystems)
– Life support (ecosystem services, resources and environment)
– Community (cultures, groups and places)

• What is intended for development?

– People (child survival, life expectancy, education, equity, and equal opportunity)
– Economy (wealth, productive sectors and consumption) 10 K. Andersson et al.
– Society (institutions, social capital, states, and regions)

• For how long?

– For example, 25 years or forever

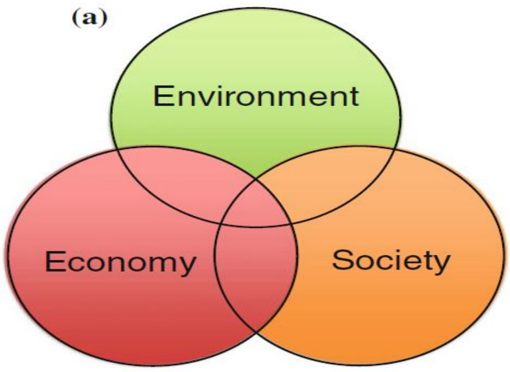
The most common international definition of sustainable development is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”, which was presented in the 1987 Brundtland Report.

Four primary characteristics of sustainable development also have been derived from the Brundtland Report:

(1) safeguarding long-term ecological sustainability,
(2) satisfying basic human needs,
(3) promoting intra-generational equity, and
(4) promoting inter-generational equity. Several secondary characteristics are also important for sustainable development, e.g., preserving nature’s intrinsic value, endorsing long-term effects, promoting public participation, and satisfying aspirations for an improved quality of life .

The importance of safeguarding long-term ecological sustainability is expressed in the Brundtland report, e.g., through such statements as, “At a minimum, sustainable development must not endanger the natural systems that support life on Earth: the atmosphere, the waters, the soils, and the living beings” and “There is still time to save species and their ecosystems. It is an indispensable prerequisite for sustainable development”. This characteristic has its origin in ecology and represents the conditions that must be present for the world’s ecosystems to sustain themselves over long periods of time. Satisfying basic human needs is at the core of the Brundtland definition of sustainable development. What are the basic human needs? The Brundtland Report mentions food, water, sanitation, clothing, shelter, energy and jobs as essential needs. Other than these basic needs, aspirations for an improved quality of life can also be met as long as they do not endanger long-term ecological sustainability. Promoting intra-generational equity and inter-generational equity is also at the core of the Brundtland definition, which emphasizes the needs of the current and future generations. All previous and future generations share the Earth; therefore, each generation must pass on the Earth and its natural resources to the next generation in at least as good of a condition as they received them (inter-generational equity). It is argued in the Brundtland Report that social equity between generations “must logically be extended to equity within each generation”. The allocation of resources among all members of a single generation should also be guided by fairness. The Brundtland Report also notes that “a world in which poverty and inequity are endemic will always be prone to ecological and other crises” .

Sustainable development is commonly represented as three pillars: economic, social and environmental. Another method used to visualize sustainable development uses the concept of carrying capacity, which represents how both economy and society are constrained by environmental limits



II. OIL POLLUTION INDUCED BY SHIPS

Some history: In 1967, the TORREY CANYON, a crude oil carrier, ran aground while entering the English channel and spilled her entire cargo of 120,000 tons of crude oil into the sea, resulting in the biggest and most catastrophic maritime pollution ever recorded upto that time and the impact it had, was disastrous.

In march 1989, the EXXON VALDEZ, ran aground in the north eastern portion of Prince William Sound(U.S.), loaded with 1,26,0000 barrels of crude oil, and spilled a majority of her cargo, again one of the largest with high attention from the media, due to its ecological impact.

These incidents and more, resulted in the need to implement a more stringent regulation to combat the threats posed by operation of ships of such gigantic sizes.

III. PREVENTION AND REACTION TO MARINE OIL SPILLS

After the disastrous incident of the Exxon Valdez, it became imminent to have a complete set of regulations, to prevent any such further incidents, which might result in another chaos an havoc in the marine environment. Hence, a regulation by the name of MARPOL-93/98 surfaced to address this issue, defining constructional and operational requirement of ships to combat different types of pollution. The first pollution category that we are going to discuss here is the one caused due to oil spills.

Oil spills can have serious effects on marine life, as highlighted by the photos as above. Such images fuel the perception of widespread and permanent environmental damage after every incident, and an inevitable loss of marine resources.

The exact nature and duration of any impacts from an oil spill depends on a number of factors. These include the type and amount of oil and its behaviour once spilt, the physical characteristics of the affected area; weather conditions and the season; the type and effectiveness of the clean up response; the biological and economic characteristics of the area and their sensitivity to oil pollution.

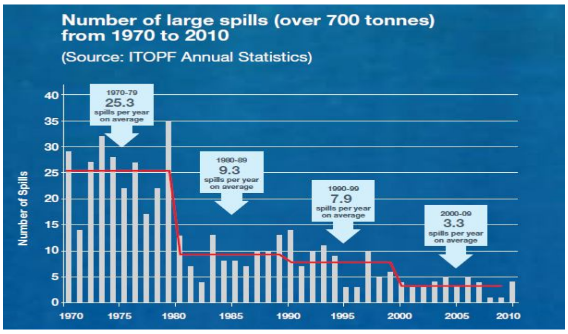
SEABIRDS- Sea birds are amongst the most vulnerable inhabitants of open waters, since they are easily harmed by floating oil. Species that dive for their food or that congregate on the sea surface are particularly at risk. Although oil ingested by birds during attempts to clean themselves by preening may be lethal, the most common cause of death is from drowning.

SEA MAMMALS like Whales, dolphins and seagull in the open sea do not appear to be particularly at risk from oil spills. Marine mammals such as seals and otters that breed on shorelines are, however, more likely to encounter oil. Species that rely on fur to regulate their body temperature are the most vulnerable since, if the fur becomes matted with oil, they die from hypothermia or overheating, depending on the season.

Contamination of coastal amenity areas is a common feature of many oil spills, leading to interference with recreational activities such as bathing, boating, fishing, angling, diving etc.
LNG ships don't carry oil cargo; hence the possibility of oil spill is limited to spills from the bunker tanks, or during leaks while taking in Bunker oil from another smaller ship. These ships run on heavy fuel oil (H.F.O.), consuming up to 180-200 tonnes of the fuel for daily usage for running the huge engines, generators, fresh water generator and other equipment.

The MARPOL convention introduced a number of radical concepts such as a requirement for new oil tankers to be fitted with segregated ballast tanks, so as to obviate the need to carry ballast water in cargo tanks, meaning less chances of contamination and hence a significant reduction in oil pollution, thereby greatly enhancing the protection of the marine environment.

Another major step has been to introduce regulations which require the oily discharges of bilge water (oil and water mix) to be done through the OILY WATER SEPARATOR' to reduce the contents to less than 15 PPM.



PREPAREDNESS FOR AND RESPONSE TO OIL POLLUTION INCIDENTS

According to shipping market analysts, world seaborne trade increased by around 135 % between 1985 and 2006. In sharp contrast, estimates of the quantity of oil spilled in to the sea during the same period show a steady decline by some 85%.In the current decade, the average number of oil spills over 700 tonnes has shrunk from over 25 per year in 1970 to just 3.7.

Despite the improvements in the area of pollution prevention, pollution incidents will inevitably still continue to occur. To address the preparedness aspect and the response to pollution incidents,IMO provides the foundation for ensuring an adequate level of response capacity and a mechanism for internation co-operation between governments and industry.

LIABILITY AND COMPENSATION

Over the years the IMO or the Internation Maritime Organisation has put again a comprehensive set of regulations covering liability and compensation for damage caused by oil transported by ships in various forms through which the shipping industry provides automatic cover of up to US $ 1 Billion for any single incident, regardless of fault. This amount adds up to cleanup the affects of pollution and provides for compensation to the victims.

GARBAGE

Ships are like small townships, with generation of all kinds of garbage sourcing from operational to personal wastes. These range from tiny cans to hug dunnages , metal scraps, discarded parts from machinery, huge amount of plastics etc. These might appear small when compared to the vast ocean, when added day by day by the entire merchant fleet, it would have a devastating affect on the marine environment.

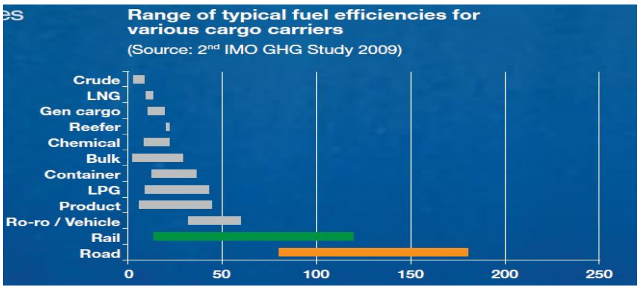
Initially, the ocean was by default considered a dumping ground for all f these wastes, only to witness the detrimental affect over the years. Soon it saw the prohibition of plastics, consequentially leading to the prohibition of all general garbage including e-waste to the sea as per the latest amendments, except for food wastes, which also are subject to some regulations in terms of distance from the nearest land, beyond which it can be dumped overboard.

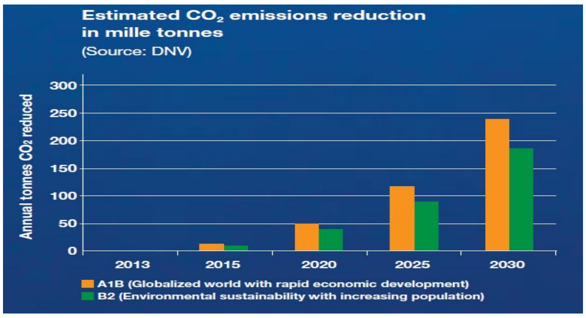
In the past few decades, the enforcement of when and where to dispose of all types of wastes produced on a ship's voyage has become better regulated through MARPOL Annex V (Regulations for the Prevention of Pollution by Garbage from Ships). The requirements are much stricter in a number of "Special Areas" but perhaps the most important feature of the Annex is the complete ban imposed on the dumping into the sea of all forms of plastic. However, although Annex V obliges Governments to ensure the provision of facilities at all ports and terminals for the reception of garbage, more work needs to be done to ensure the availability of adequate reception facilities in every port. IMO instigated an "Action Plan on tackling the inadequacy of port reception facilities", which was completed after three years' work in 2010. IMO also embarked on a complete revision of Annex V and of the associated guidelines for its implementation, to take into account new Technological developments.

IV. AIR POLLUTION FROM SHIPS

Although air pollution from ships does not have the direct cause and effect associated with, for example, an oil spill incident, it causes a cumulative effect that contributes to the overall air quality problems leading to poor respiratory health encountered by populations in many areas, and also affects the natural environment, such as through acid rain.MARPOL Annex VI, first adopted in 1997, limits the main air pollutants contained in ships exhaust gas, including sulphur oxides (SOX) and nitrous oxides (NOX), and prohibits deliberate emissions of ozone depleting substances.MARPOL Annex VI also regulates shipboard incineration, and the emissions of volatile organic compounds from tankers. In October 2008, IMO adopted the Revised MARPOL Annex VI and the NOX Technical Code 2008, which entered into force on 1 July 2010. The main changes are a progressive reduction in emissions of SOX, NOX and particulate matter and the extension of designated emission control areas (ECAs) for more stringent control of the emission of SOX to NOX and particulate matter (PM) as well. Under MARPOL Annex VI, the global sulphur cap for fuel oil used on-board ships is reduced initially to 3.50%m/m (from the current 4.50%), effective from 1 January 2012; then progressively to 0.50%, effective from 1 January 2020,subject to a feasibility review to be completed no later than 2018. The sulphur limits for fuel oil applicable in ECAs for SOX and particulate matter are 1.00%,and further reduced to 0.10%, effective from 1 January 2015. Progressive reductions in NOX emissions from marine diesel engines are also included, with more stringent controls being a "Tier II" emission limit required for those marine diesel engines installed on or after 1 January 2011; then with the most stringent controls being "Tier III" emission limit for marine diesel engines installed on or after 1 January 2016, that are used on ships operating in ECAs designated for controlling NOX. Marine diesel engines installed on or after 1 January 1990 but prior to 1 January 2000 are also required to comply with "Tier I" emission limits, if an approved method for that engine has been certified by an Administration. The Control of Greenhouse Gas Emissions from International Shipping IMO recognizes the increasing importance and urgency to control greenhouse gas (GHG) emissions worldwide and is determined to be in the frontline of the global campaign to tackle this defining challenge of our age. According to the Second IMO GHG Study 2009, the most comprehensive and authoritative assessment of the level of GHG emitted by ships, as well as the potential for reduction, international shipping was estimated to have emitted 870 million tonnes, or about 2.7% of the global emissions of carbon dioxide (CO2) in 2007.Exhaust gases are the primary source of emissions from ships. Carbon dioxide is the most important GHG emitted by ships, both in terms of quantity and of global warming potential, other GHG emissions from ships are less important.

In terms of environmental impacts, the fraction of shipping that occurs close to land accounts for an important contribution. Ports are often located in or close to large cites, and the sea traffic in and out of ports can affect the population in the area due to emissions to the air and water and from noise and waves.





"**MARPOL ANNEX VI** sets limits on SOx and NOx emissions from ship exhaust and prohibits release of ozone depleting substances.

The Control of Greenhouse Gas Emissions from International Shipping

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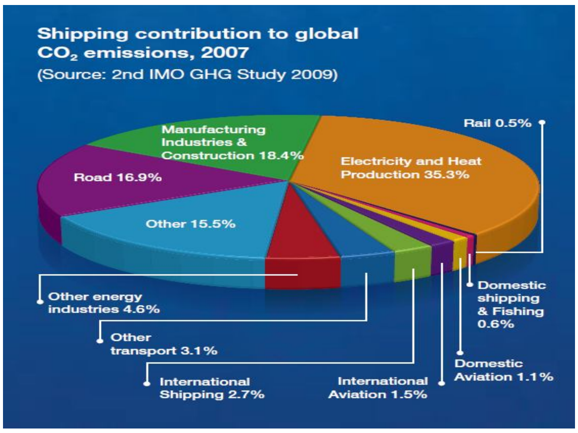


Ship Resistance

Ship movement through water generates a resistance from the water. This resistance depends primarily on a ship's speed (a standard approximation correlates the propulsive power requirement with the third power of a ship's speed) and on a resistance coefficient, which in turn depends on the hull (e.g., the shape, state, and wetted surface). However, a ship operates in the natural environment, which can lead to the attachment and subsequent growth of various marine organisms on the surface of the hull. These organisms can significantly enhance the hull drag, increasing the power needed by the engine to propel the ship . It has been estimated that fuel consumption increases by 6 % for every 0.1 mm increase of hull roughness due to fouling. To reduce this phenomenon, so-called "antifouling" treatments are often used to hinder marine growth. Antifouling paints are applied to hulls to prevent the growth of fouling organisms, such as barnacles, mussels, bryozoans and algae. Antifouling systems are required when unwanted biological growth occurs, and the need to protect ship hulls from fouling is as old as the use of ships. However, the release of biocides from antifouling into the water can result in a harmful impact on the marine environment.

Ballast water discharge and the environment

Ballast water discharges by ships can have a negative impact on the marine environment. The discharge of ballast water and sediments by ships is governed globally under the Ballast Water Management Convention, since its entry into force in September 2017. It is also controlled through national regulations, which may be separate from the Convention, such as in the United States.

Cruise ships, large tankers, and bulk cargo carriers use a huge amount of ballast water, which is often taken on in the coastal waters in one region after ships discharge wastewater or unload cargo, and discharged at the next port of call, wherever more cargo is loaded. Ballast water discharge typically contains a variety of biological materials, including plants, animals, viruses, and bacteria. These materials often include non-native, nuisance, exotic species that can cause extensive ecological and economic damage to aquatic ecosystems, along with serious human health issues including death here are hundreds of organisms carried in ballast water that cause problematic ecological effects outside of their natural range. The International Maritime Organization (IMO) lists the ten most unwanted species as:[1]

- Cholera Vibrio cholerae (various strains)
- Cladoceran Water Flea Cercopagis pengoi
- Mitten Crab Eriocheir sinensis
- Toxic algae (red/brown/green tides) (various species)

- Round Goby Neogobius melanostomus
- North American Comb Jelly Mnemiopsis leidyi
- North Pacific Seastar Asterias amurensis
- Zebra Mussel Dreissena polymorpha
- Asian Kelp Undaria pinnatifida
- European Green Crab Carcinus maenas

To react to the growing concerns about environmental impact of ballast water discharge, the International Maritime Organization (IMO) adopted in 2004 the "International Convention for the Control and Management of Ships' Ballast Water and Sediments" to control the environmental damage from ballast water. The Convention will require all ships to implement a "Ballast water management plan" including a ballast water record book and carrying out ballast water management procedures to a given standard. Guidelines are given for additional measures then the guidelines.

The goals of the convention are to minimise damage to the environment by:

- Minimise the uptake of organisms during ballasting.
- Minimising the uptake of sediments during ballasting.
- Ballast water exchange while at sea (the ship should be minimum 200 nautical miles from shore with a depth of minimum 200 metres and can use the flow through or sequential method). At least 95 percent of the total ballast water should be exchanged.
- Treatment of the ballast water by chemical or mechanical influences (UV-radiation, filter, deoxygenation, cavitation, ozone…)

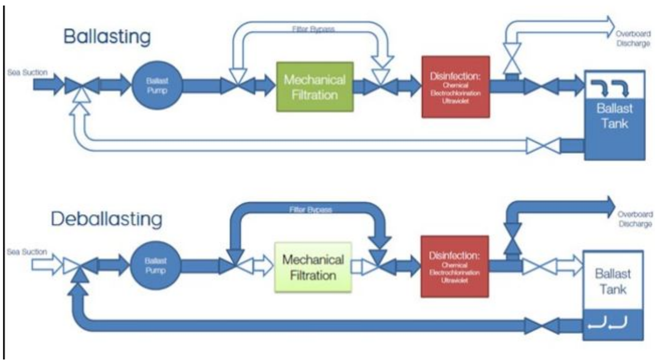
Control measures include:

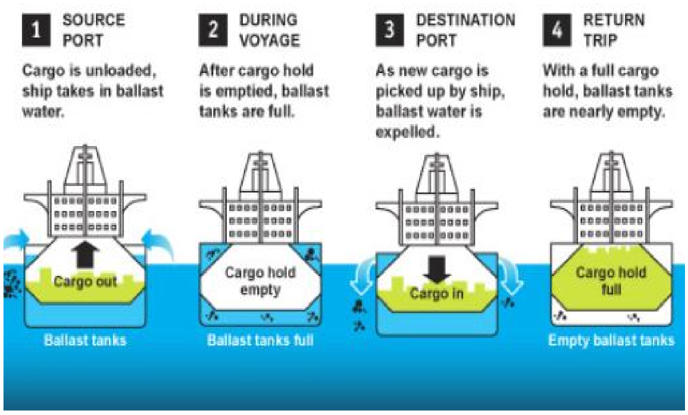
- International Ballast Water Management Certificate
- Ballast water management plan
- Ballast water record book
- Ballast water treatment

The practical method to minimize the introduction of unwanted organisms from the discharge of ballast water is the water ballast exchange. The exchange procedure shall be carried out in an "open ocean condition" at least 200 nautical miles from the nearest land and in waters at least 200 metres in depth. It can be accomplished by either the sequential empty-refill method, by flow-through method or by or dilution method whereby tanks are overfilled by pumping in additional water. Due to limited biological efficiency the ballast water exchange at sea is to be regarded as an interim measure.

- Flow-through method – This 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. Applying the flow through method does not alter the stability, stress, and ship attitude.

- Sequential method – This method entails emptying ballast tanks completely and refilling with open-ocean water. During ballast water exchange sequences there may be times when, for a transitory period, the criteria for propeller immersion, minimum draught or bridge visibility cannot be met. Emptying of certain tanks may lead to major reduction of stability , higher stresses, high sloshing pressures and increased probability of bow slamming.





V. RECYCLING

When ships reach the end of their working lives, recycling is the most environmentally friendly way to dispose of them. Many of the components and virtually all of the steel are re-used in the countries where the ships are recycled,into new ships, in agriculture, in hospitals, at homes, and in other products.

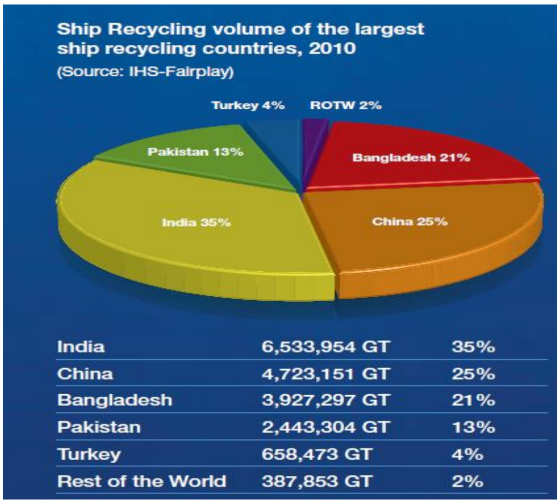
However, there are concerns about environmental and working conditions in ship recycling yards.

In May 2009, IMO adopted the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009 (the Hong Kong Convention). The new Convention balances safety and environmental concerns with the commercial realities of seaborne trade and the ship recycling industry.

Following the adoption of the Convention, Member States of IMO will need.**1 t**

- **1 to initiate work to accede to the Convention at the earliest possibleopportunity so as to expedite its entry into force;**
- **2 to initiate action to provide technical assistance to requesting countrieswithout awaiting the Convention's entry into force; and**
- **3 to initiate action, as may be necessary, to ensure the effectiveimplementation and proper enforcement of the Convention whenit comes into force.**

Currently IMO is working on the development and adoption of guidelines associated with the Hong Kong Convention. Six guidelines are envisaged by the Convention. The "guidelines on the development of the Inventory of Hazardous Materials" and the "guidelines for the development of the Ship Recycling Plan" have already been adopted. The remaining guidelines are expected to be finalized and adopted during 2012.



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