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MARITIME TRANSPORT COMMITTEE

COST SAVINGS STEMMING FROM NON-COMPLIANCE WITH INTERNATIONAL ENVIRONMENTAL REGULATIONS IN THE MARITIME SECTOR

This report examines the the unfair commercial advantage afforded to substandard shipowners who fail to comply with international environmental regulations that apply to their ships. It has been prepared for the Maritime Transport Committee and is being made available to a wider audience.

Organisation for Economic Co-operation and Development 2003
Organisation de Coopération et de Développement Economiques

FOREWORD

This report examines the unfair commercial advantage afforded to substandard shipowners who fail to comply with international environmental regulations that apply to their ships.

It is the second in a series intended to highlight the cost savings and ensuing competitive advantage that such shipowners gain over their law-abiding counterparts. The first report examined the unfair economic advantage to be derived through non-compliance with international rules pertaining to safety at sea* and the third will seek to quantify how unscrupulous shipowners/operators can unfairly benefit from non-compliance with international rules related to the manning of vessels.

In January of 2003 this report was presented to the Maritime Transport Committee (MTC) of the Organisation for Economic Co-operation and Development. It was declassified by the MTC at that meeting.

The report was prepared by Philippe Crist. It is published on the responsibility of the Secretary-General of the OECD.

* “Competitive Advantages Obtained by Some Shipowners as a Result of Non-observance of Applicable International Rules and Standards”, 1996

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SUMMARY

On 19 November 2002, the aged single-hulled product tanker Prestige broke in two and sank off the coast of Galicia after nearly six days of struggling in heavy seas. Nearly two years earlier, another aged single-hulled product tanker, the Erika, similarly broke in two and sank off the coast of Brittany. In the past ten years another three major oil spills have occurred off the coasts of Europe – the Sea Empress (Milford Haven, 1996), the Braer (Shetland Islands, 1993) and the Aegean Sea (Galicia, again, in 1992). In each of these cases, distressingly familiar images of soiled beaches, dead wildlife and desolate coastal communities have made their way around the world. If nations have come together to craft international environmental regulations pertaining to maritime transport, surely it is to prevent these types of accidents from occurring.

Yet every year, unscrupulous ship operators release more oil illegally into the marine environment than all of these spills combined. Put in another perspective, according to one recent study, the illegal discharge of oil into the sea through routine operations is equal to over eight times the Exxon Valdez oil spill or over 48 times the 1997 Nakhodka spill off the coast of Japan – every year.

Oil pollution is not the only environmental impact stemming from maritime transport. Garbage and sewage discharges, air pollution, ecosystem damage stemming from hull coatings and the devastating impacts generated by the introduction of intrusive non-native species through ballast water discharges are all addressed through a comprehensive international regulatory framework negotiated at the International Maritime Organisation (IMO).

Most ships and shipowner/operators actively seek to comply with this body of environmental regulations. Nonetheless, recent evidence from port state inspections reveal that nearly half of vessels inspected violate at least one aspect of the international environmental rules concerning the stowage and disposal of oil. Not all of these violations are evidence of wilful misconduct, nor are they all serious, but they do underscore that compliance with international environmental rules still leaves something to be desired.

The real problem lies with a relatively small percentage of vessels and owners that persist in consistently operating their vessels in full contravention to the IMO's body of environmental regulations. In relative terms, the numbers are small – approximately 10-15% of the world fleet. However, in absolute terms, this subset of owners accounts for a large number of vessels. The world fleet is composed of nearly 88 000 vessels of which approximately 50 000 trade internationally[1]. Given a compliance rate of 85% to 90%, that still leaves potentially 5 000 to 7 500 substandard commercial vessels polluting the seas through their non-compliance with international environmental regulations.

Worse still, many of these operators are actually *rewarded* for breaking these rules in those parts of the world where the risk of being apprehended is small and the ensuing fines, if any, are low. Savings derived by not complying with the IMO's regulations leads to lower operating costs that can be used to derive an unfair advantage in the notoriously competitive ship charter market. When added to the cost savings derived by not complying with international safety and crewing requirements, a substandard operator can substantially undercut quality vessels – especially when, as often is the case, the substandard vessel is older or is operating in a non-remunerative charter market.

[1] Lloyd's Register, 2001 (87 939 ships over 100 GT) – the International Chamber of Shipping estimates the world commercial fleet to be comprised of approximately 50 000 vessels.

Frustratingly, the opposite is not true – the quality shipowner is usually not rewarded for complying with MARPOL and other related international environmental rules. In many cases, they might even be penalised by having to go out of their way in order to comply with the rules. Herein lies the insidious impact that substandard shipping can have on this global industry – as long as substandard operators get away with breaking the rules and make money and gain market share by doing so, other operators will be tempted to follow in their footsteps with repercussions on the safety of vessels, the well-being of crews and, in the present case, on the environment.

It is important, therefore, to highlight this problem and seek to quantify the unfair competitive advantage thus derived by substandard operators in order for policy makers to best craft their response. This paper builds on previous work undertaken by the MTC on the cost savings unscrupulous ship owners and operators could realise by running substandard ships. It seeks to characterise and identify the costs avoided by substandard operators through non-compliance with international environmental regulations.

Six major points stand out from the report's analysis:

- **First order costs of compliance are not high**

  The first is that the "first order" costs of compliance on "average" ships are not that great. These costs include the capital, maintenance and repair costs for environmental equipment. They also include the costs for disposing of residual wastes not treated by on-board systems. The former typically range approximately USD 30 000 per year (with variations due to ship size, type and trading patterns). The latter are variable according to the amount of fuel consumed (and hence, fuel sludge produced), oily bilgewater build-up, number of crew and number of days at sea. These costs can theoretically range as high as over USD 150 000 per year for a VLCC and over USD 55 000 per year for a medium-large container vessel. Given average operating costs, these amounts can account for anywhere from 3.5% to 6.5% of the ship's operating costs. However, when margins are tight (*e.g.* when revenues are below the costs of financing and operating the ship), some owners and operators might be tempted to avoid these costs, especially as non-compliance with environmental regulations does not directly endanger ship, crew or cargo.

- **Avoiding equipment maintenance leads to high second-order compliance costs**

  Avoiding the first-order costs outlined above often results in equipment failure meaning that no wastes can be treated on board. These wastes build up and, according to international regulations, must be discharged in port. While the costs for discharging these wastes vary (anywhere from ~USD 20/m^3 to over USD 115/m^3 for oily wastes depending on the region), it remains an expensive option that many substandard operators might choose to forgo. Their savings are directly proportional to the wastes they produce (and dump illegally overboard) ranging for example from ~USD 50 000 to nearly USD 400 000 per year in the examples given in this paper.

- **Older, less-maintained vessels and non remunerative markets increase the relative cost of compliance**

  Generally, as ships get older, their environmental compliance costs increase. One might expect compliance costs for an older and poorly maintained VLCC, medium-large container carrier and a capesize bulker to be in the order of USD 273 700, USD 113 500 and USD 142 700, respectively. These costs are exacerbated in a non-remunerative market – *e.g.* with charters negotiated at 30% below operating costs, environmental compliance costs can account for 11% to 15% of the ship's revenue in this example.

- **Fines must be adapted to the level of cost savings derived through non-compliance**

  Penalties for non-compliance are effective if the risk of apprehension *and* prosecution for offenders is high and the level of the fine sufficiently elevated to make environmental compliance a more economical solution. The former relies on effective ocean surveillance, port state inspections and judicial processes whereas the latter depends on the effective level of fines levied. A deterrent fine should at a very minimum be equal to the costs avoided through non-compliance. Despite recent increases in the level of penalties, it is not yet clear that the average fine levied on merchant ships for breaches of MARPOL conform to this definition.

- **New environmental regulations will heighten the need to combat substandard practices**

  As realisation of the environmental risks posed by shipping grows, so too will future compliance costs. The advent of several necessary international instruments will most likely have and impact on the environment-related costs of shipping. This paper projects that these new costs will be anywhere from 1.5 to 3 orders of magnitude greater than current environmental compliance costs for average vessels. This highlights the need to be especially vigilant of substandard practices as the non-complying operator will be able to derive an even greater commercial advantage over the quality ship owner of the future.

- **Dirty fuels lead to high storage and disposal costs for sludges – and to cost savings through illegal ocean dumping for substandard operators**

  Heavy fuel oil (HFO) sludges are the greatest source of illegal oil discharges from ships. As long as ships' engines run on these extremely "dirty" final products of the refining chain, ships will accumulate sludges that, according to international regulations, can only be disposed of in port reception facilities and/or burned in approved incinerators. Weaning the maritime sector away from these fuels and towards cleaner sources of energy, much as what has been done for land transport, would go a long way towards reducing sludge production, oil discharges and, ultimately, the competitive advantage accruing to non-compliant vessels.

COST SAVINGS STEMMING FROM NON-COMPLIANCE WITH INTERNATIONAL ENVIRONMENTAL REGULATIONS IN THE MARITIME SECTOR

The world's maritime transport system has been an essential element in the growth of global prosperity since the first trading ships sailed several thousand years ago. Today, perhaps more than ever, a properly functioning and competitive maritime transport system is essential for ensuring continued economic and social well-being. However, as with any industrial sector (although arguably less than most other industrial sectors), maritime transport has been the source of both spectacular releases of pollution as well as a more subdued and constant stream of waste and garbage into the seas and onto shorelines.

Countries, recognising that certain fundamental rules were necessary to reduce the incidence of pollution from ships, have developed an international body of environmental regulations for the shipping sector. Most shipowners and operators have chosen to abide by these and have complied with these rules. However, a certain number of less scrupulous operators and owners have taken advantage of the difficulty the international community has faced in enforcing these regulations, and have sought to either avoid complying, or only partially comply, with these rules and regulations. Insofar as such owners and operators are able to avoid paying for equipment, operations, crew and waste disposal costs, they can derive an unfair competitive advantage over other shipowners and operators.

This study seeks to gauge the nature of that competitive advantage in order to aid national administrations seeking to eradicate sub-standard shipping. Calculating the costs associated with environmental compliance is a very complex task as these vary according to a number of factors including ship type, size, installed equipment, propulsion systems, and the geographic regions visited. As such, it is difficult to give an average cost of compliance and/or savings incurred through non-compliance.

Furthermore, collecting operating cost data from shipowners and operators is a difficult exercise as many feel that such data is commercially sensitive. However, using a mix of primary and secondary data sources, this paper attempts to estimate the cost implications of the principal environmental regulations governing shipping and will seek to illustrate the type of cost savings that substandard owners can derive through non-compliance with these rules.

Regulatory background

If sub-standard operators are able to derive a competitive advantage from non- or partial-compliance with environmental regulations, it is often because they feel that this course of action is worth the risk. That is, the financial benefit from non-compliance more than outweighs the chances of being caught and any financial penalties they might face if discovered[2]. In order to better understand the risks, one must keep in mind that the responsibility for the elaboration and enforcement of these rules is divided among several actors and institutions. These include the International Maritime Organisation (IMO), Flag States, class societies and the Port States.

2 . In some cases, however, non-compliance may be the result of poor management rather than a calculated and deliberate attempt to derive cost savings.

International environmental regulations for shipping: the actors

International Maritime Organisation

First and foremost among these actors is the IMO. It is here that nations form the common body of law that serves to guide international maritime transport. Through its international Conventions, the IMO sets the regulatory framework for reducing the incidence of pollution from ships. This framework has evolved over time, as has awareness of the maritime sector's environmental impact. Currently the bulk of international regulations pertaining to pollution prevention for ships are contained in the International Convention for the Prevention of Pollution from Ships of 1973 as amended in 1978 and thereafter (MARPOL 73/78). This Convention seeks to reduce pollution from ships by specifying both structural requirements and performance standards for various ship subsystems that represent a potential source of pollution.

Nations have also sought to address other environmental impacts from shipping within the IMO – most notably concerning the ecosystem impacts from the use of tin-based anti-fouling compounds and the spread of invasive species through the release of ballast water. These negotiations have led to a Convention that is in the process of being ratified in the case of the former, and to efforts to develop an appropriate instrument to address the latter. While the bulk of this report will focus on those elements of MARPOL 73/78 that have already come into force, some discussion will be devoted to the cost implications of the Antifouling and developing Ballast Water Conventions.

Flag states and class societies

The principal responsibility for complying with the IMO's regulatory framework has always remained with Flag States. These states traditionally exercise direct control over national fleets and their crews that tended to be nationals of those states. However, the development of "open" registries – where non-national shipowners could register their ships in national registries with a sometimes-tenuous link to the flag – saw the direct ship-Flag State-national crew link weakened. This of itself has not necessarily been a bad thing as the development of open registries and the international sourcing of crews has offered cost savings to owners and new employment opportunities for seafarers around the world. However, this shift of registries has rendered the control of the quality of world fleets' and their crews more problematic.

Most Flag States carry out their regulatory responsibilities either directly or through intermediary Class Societies. However, a certain number of states have sought to reduce their expenditures related to the administration of their fleet and/or have sought to develop their registry solely as an income-generating venture. These and other smaller states simply do not have the budgets and/or administration necessary to ensure that their fleets continue to meet IMO requirements. Class Societies have played an increasingly more important role in ensuring the safety, seaworthiness and quality of these national registries. Yet, it is commonly recognised that stiff competition in the classification/certification market has led to the emergence of certain Class Societies willing to cut corners in order to gain or retain clients.

Port states

Given the complexities inherent in an international framework for registry and class certification, Port States have increasingly exercised their right to inspect incoming vessels. Port state inspections have become the principal rampart against substandard shipping, at least to the extent that countries are able to, and choose to, exercise this prerogative. Many countries have organised their Port State Control Agencies into international groupings ("Memoranda of Understanding" – MOU) that exchange information among participants. The principal MOU's cover Europe, the Asia-pacific region and North America. Not all ships are inspected, but, with the development of targeted boarding matrices, Port State Control inspections have a fairly reasonable chance of catching the most egregiously substandard ships. This threat of discovery, however, only exists in regions with strong and proactive Port State Control administrations – there are many parts of the globe where these are lacking and where substandard operators can operate with relative impunity.

THE REGULATORY FRAMEWORK

The international convention for the prevention of pollution from ships: MARPOL 73/78

Background

The body of MARPOL 73-78 and its amendments are divided into six thematic annexes covering different pollution-source vectors from maritime transport. These are:

- Annex I: Prevention of Pollution by **Oil**.
- Annex II: Control of Pollution by **Noxious Liquid Substances**.
- Annex III: Prevention of Pollution by **Harmful Substances in Packaged Form**.
- Annex IV: Prevention of Pollution by **Sewage** from Ships.
- Annex V: Prevention of Pollution by **Garbage** from Ships.
- Annex VI: Prevention of **Air Pollution** from Ships.

Each of these annexes details technical requirements and standards to which ship operators and owners must adhere in order to comply with the law. All member states of the International Maritime Organisation must accept and comply with the first two annexes of MARPOL. Annexes III through VI are voluntary – that is, countries may choose not to ratify these texts. However, once one of these annexes comes into force and a country ratifies it, it becomes binding. Five of the annexes have come into force and a substantial portion the world tonnage is registered in countries having signed onto these texts. Annex VI will come into force when countries representing at least 50% of world ship tonnage have ratified it. Although few countries have formally ratified the text, many shipowners and operators are already seeking to comply with its rules.

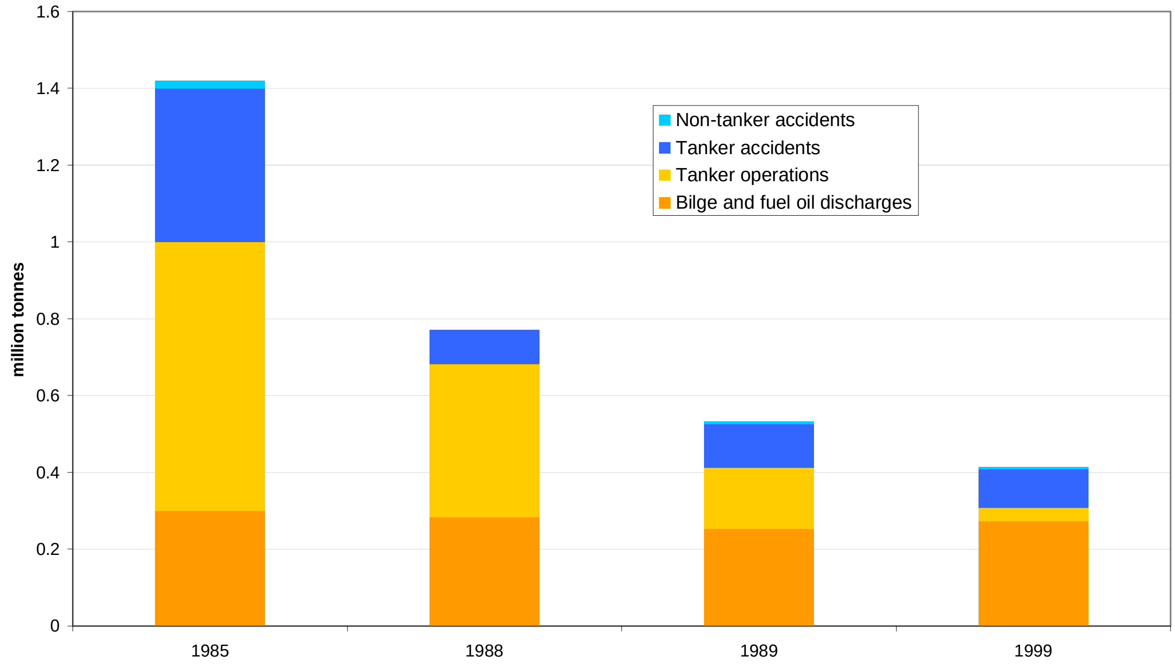
Status of MARPOL 73-78 annexes (November 2002)				
MARPOL annex	Entry into force year	Contracting parties (out of 193 IMO members	% of world tonnage	OECD contracting parties (out of 30 members)
I: Prevention of pollution by oil	1983	123	96.92	30
II: Control of pollution by noxious liquid substances	1983	123	96.92	30
III: Prevention of pollution by harmful substances in packaged form	1992	105	82.95	28[1]
IV: Prevention of pollution by sewage from ships	2003	89	51.14	20[2]
V: Prevention of pollution by garbage from ships	1988	110	89.26	29[3]
VI: Prevention of air pollution from ships	(n/a)	6	24.97	2[4]

1. Mexico and Turkey have not yet ratified Annex III.
2. Australia, Canada, Iceland, Ireland, Mexico, Netherlands, New Zealand, Korea, Turkey and the United States have not yet ratified Annex IV.
3. Canada has not yet ratified Annex V.
4. Within the OECD, only Norway and Sweden have as of yet ratified Annex VI.

Annex I: Prevention of pollution by oil

Annex I of the MARPOL Convention grew out of a long history of efforts to reduce oil pollution at sea. These efforts included the OILPOL Convention of 1954 and its amendments of 1962, 1969 and 1971. In this Convention, ships were prohibited from discharging significant quantities of oil (over 100 parts per million - ppm) within 50 miles of land. Furthermore, signatories were required to promote the development of port-side reception facilities for oily wastes. These two elements of oil pollution prevention – the reduction of oily effluent discharge at sea and the development of port-side reception facilities, still serve to frame the IMO's efforts to prevent operational oil pollution. The 1954 convention also underscored the fact that, despite catastrophic oil spills resulting from tanker groundings and/or losses at sea, the principal source of ship-source oil pollution was, and remains, routine operational discharges. (see figure below).

Estimates of inputs of oil into the world's oceans from ships



Source: IMO,1989, US NRC, 2002.

Many of the OILPOL clauses were incorporated into the first annex of the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL). Annex I of this Convention, as amended in subsequent years, sets out rules for ship construction and operation in order to reduce the risk of oil pollution. As can be expected, these requirements carry sometimes-substantial costs for ship owners and operators. However, before looking at the regulatory requirements of Annex I, it might be helpful to understand the sources of operational oil discharges from ships.

The problem: Oil discharges from ships

Oils and other hydrocarbon substances are essential for the operation of most sea-going vessels. These substances serve as fuel (heavy oil bunkers or marine diesel fuel), lubrication for the ship's engines and machinery and as cargo for tankers ensuring the global supply of energy. There are various technical sub-systems aboard ships that handle the containment, flow and use of these substances and each can be a source of oil/fuel leakage and pollution. These systems include the following: hull/ballast tank systems, cargo tank and cargo pumping systems (for oil and product tankers), fuel tank and piping systems, engine and propulsion systems, and the oily water treatment and discharge system.

Hull and ballast systems

Failure of the structural integrity of a ship's hull has been the most visible cause of accidental oil spills. Indeed, once the hull of a single-walled tanker is ruptured, there is little that can be done to prevent the massive outflow from the affected cargo tanks. Although proponents of double-hulled construction for oil tankers had pushed for changes in international legislation in the past, it was not until the grounding of the single-hulled Exxon Valdez in 1989 and the subsequent passage of the 1990 United States Oil Pollution Act (OPA 90) that maritime transport operators were faced with mandatory requirements to phase-out single hulled tankers. Although OPA 90 only impacted US-flagged vessels and ships calling on ports in US waters, its impact soon spread as the IMO considered and adopted amendments to Annex I of MARPOL calling for the phase-out of single-hulled tankers. Following the sinking of the tanker Erica off the coast of France in 1999 the IMO agreed to an accelerated timetable for phasing out single hulled tankers that will see most single hulled tankers withdrawn from the world fleet by 2015 at the latest. Oil tankers built since 1994 are all required to have double hulls or an IMO-approved functional equivalent.

In order to maintain their structural integrity and seaworthiness, ships must be able to take on and discharge ballast water in order to compensate for changes in the ship's buoyancy as cargo is loaded or unloaded. In the past, different ship designs called for this water to be stored directly in cargo and/or bunker tanks (in the case of oil tankers and other product tankers) or in segregated ballast tanks. It was the common practice of oil and product tankers to load and discharge ballast water directly from cargo/bunker tanks that led to high rates of oil discharges into the sea. Following MARPOL 73/78, tankers were required to designate "clean" cargo tanks (CBT) to serve as ballast tanks, or to be built or retrofitted with a completely segregated ballast system (SBT). While tankers still have the right to take on ballast in cargo tanks in order to stabilise the ship in extreme weather, this is a relatively rare occurrence and, in general, ballast water is rarely directly mixed with liquid cargoes.

Cargo tank and pumping system for oil tankers

Following the delivery of their cargo and before the loading of new cargo, oil tanker cargo spaces must often be cleaned to avoid cross-contamination with different grades of oil products. In the past, this cleaning was accomplished through the use of high-pressure water spraying. The resulting oily water was either directly discharged (representing a non-inconsequential loss of money for the cargo owner) or – more often – discharged to a settling tank. After the oil had separated to the top, the remaining water was discharged from the bottom. The difficulty inherent in this system was that ships often did not precisely stop the discharge when the oil-water interface was reached. Furthermore, the formation and presence of oil-water emulsions and oil sludges made clean water discharges difficult to achieve. Following MARPOL 73/78, tankers gradually moved to crude oil washing systems that washed the cargo tanks using the cargo itself. These systems have greatly reduced the discharge of oil-water mixtures from tankers.

Nonetheless, tankers will typically wash 3-4 cargo tanks at least two times during the year in order to facilitate inspections and/or repair work. The industry group INTERTANKO estimates that approximately 6 000 m^3 of wash water is discharged by an average tanker per year. These operations if not undertaken properly and with functioning monitoring and oil separation equipment, represent a potential source of oil pollution.

Sediments also collect in cargo tanks of tankers and must be transferred to the ship's "slop" tank for later discharge to a port waste reception facility and/or disposed of in a another manner consistent with MARPOL 73/78 (*e.g.* through incineration).

Fuel tank and piping system

Ships generally rely on either heavy fuel oil (a blend of residual oils with lighter oils to achieve a desired viscosity) or marine diesel as fuel. These are loaded into bunker tanks and are piped to the engine room for filtration, treatment and use. Poorly maintained pipelines, joints and/or cracks in the bunker tanks can be a source of fuel oil leakage into the ship's hull. These leaked oils collect in the ship's bilge where they mix with water and other compounds (*e.g.* cleaning detergents). The ensuing oily-water mixture must be pumped out of the ship or else it can impact the ship's stability. In the past, these mixtures were pumped directly overboard. Now, however, oily bilgewater must be either be processed in order to remove oil compounds before it is allowed to be discharged overboard. Oil separated from this water must be kept on board and or disposed of in a manner consistent with MARPOL 73/78.

Finally, heavy fuel oil contains a small percentage of sludge that cannot be used as fuel (typically between 1.5% to 2% of the fuel oil volume). This sludge must be discharged in a port waste reception facility or otherwise burned onboard (either by being homogenised and burnt with fuel or by being burnt in an incinerator).

Engine and propulsion system

Even well-maintained engines, gearboxes, propeller shafts and other associated propulsion systems will leak small quantities of fuel and lubricating oil. As the level of maintenance goes down and as the age of the engine, gaskets, etc, goes up, so will the quantities of leaked oil. These can be caught in drip-pans and processed directly into the slop tank but more likely than not, these oils will find their way into the bilge where they will mix with water and other compounds generated by the daily operation of the vessel. This bilgewater must be disposed of in accordance with the requirements of MARPOL 73/78 as detailed in the preceding section.

Oily water treatment and discharge system

Eventually, all water containing oil collected in the slop tanks and/or in the bilge of the ship must be processed through an oil-water separating system (OWS) before being discharged overboard Alternatively, these oil-water mixtures must be kept on board and discharged to a port reception facility. Leaks in the oil-water separating system's piping and/or in the slop tank can be a source of oil. Water discharged overboard must contain only trace amounts of oil (15 ppm – as this amount of oil should not leave a sheen on the surface of water, any visible sheen in a ship's wake can be interpreted as evidence of a discharge above 15 ppm). This oil concentration is monitored either manually or automatically. Failure to shut off the discharge flow when this concentration is exceeded will result in oil being released into the sea.

The United States National Research Council's (NRC) recent report "Oil in the Sea: Inputs, Fates and Effects" (2002), provides an estimated breakdown of oil inputs into the sea by ship subsystems (see table below). Two points stand out from reading this table. The first is that ships that are not in compliance with MARPOL are responsible for almost 98% of oil discharged through vessel operations. The second point is that fuel oil sludges compromise almost 85% of all oil illegally discharged through vessel operations. Given the NRC figures and assuming an average disposal cost of USD 50 per tonne, illegal dumping of fuel sludges alone saves substandard operators nearly 12.8 million USD per year.

Oil Inputs into the sea from maritime transport, 1999 (tonnes)

	Operational tanker discharges	Tanker bilge oil discharge	Non-tanker bilge oil discharge	Fuel sludge discharge, all vessels	Totals
Compliant vessels	7 056	36	171	0	7 263
Non-compliant vessels	29 381	1 129	15 436	255 700	301 646
Totals	36 437	1 165	15 607	255 700	308 909

Annex 1. Regulatory Requirements for Operational Procedures, Equipment and Ship structure.

The requirements of Annex I are complex and address many different ship types. This section will look at the principal requirements that have an incidence on the capital and operating costs of vessels.

Annex I develops two approaches to controlling oil pollution from vessels. The first focuses on procedures and processes that must be adhered to in order to ensure the minimum release of oil into the sea. These requirements outline certification, record-keeping, discharge procedures and other criteria regulating shipboard operations. The second approach emphasises technical design specifications that ships must adhere to in order to minimise the accidental or operational discharge of oil. Whereas the first approach involves the responsibilities of crews, Flag and Port states in ensuring compliance, the second relies on the structural make-up of the ship to prevent oil pollution. Finally, Annex I generally differentiates requirements according to ship category (tankers vs. all other vessels) and size classes (as measured by gross ton weight). These requirements will be highlighted where appropriate.

Certification and record-keeping

As with many other of the MARPOL annexes, one of the principal requirements of Annex I is that ships must carry on board valid international certificates indicating that they comply with the requirements of the Convention. In the case of Annex I, this certificate is the International Oil Pollution Prevention Certificate (IOPP – required for all oil tankers over 150 gwt and all other ships above 400 gwt). This certificate is issued by the Flag State or a class society on behalf of the Flag State after an initial survey. A periodical survey must be undertaken every 5 years and an intermediate survey must be taken at least once in the period between periodical surveys. Finally, vessels must also have onboard a Shipboard Oil Pollution Emergency Plan (SOPEP) that details actions to take and operational procedures to follow in the event of an accidental outflow of oil. Developing such a plan costs approximately USD 3-5 000 per vessel and updating it costs about USD 500.

Ships are also required to keep a detailed record of all movements of oil and oily wastes on the ship and to the sea and/or port reception facilities. Tankers are required to keep a log of all product movements as well. These entries are to be logged into the Oil Record Book and must be signed by the person in charge of the operation and each page must be signed by the master. This provides a written record of the storage, processing and discharge of oil and oil-water mixtures that can be checked against the ship's discharge data recorders and correlated to the ship's estimated production of oily waste. Software for tracking this information costs approximately USD 1 000 per year and logging duties are estimated to take an officer approximately one hour per day.

Ship's masters are also required to report any oil pollution incident observed while at sea whether or not they are responsible. This reporting requirement calls for the master to fill out a form and to process it through the Flag State.

Annex 1. Oil/oil mixture discharge requirements

Adherence to these rules relies on the responsible actions of shipowner/operators and their crews. As such, they also represent one of the areas where Annex I can most easily be subverted.

These requirements are differentiated according to whether or not the vessel is underway within a specially designated "special area". These areas cover bodies of water that, because of their geographic situation, are less easily flushed by ocean currents. Therefore all discharges of oil/waste are prohibited except in very specific circumstances. For the purposes of Annex I of MARPOL 73/78, the designated special areas are the:

- Mediterranean Sea.
- Baltic Sea.
- Black Sea.
- Red Sea.
- The “Gulfs”.
- Gulf of Aden.
- Antarctic.
- North West European Waters.

While these areas cover relatively little of the ocean's surface, they comprise some of the world's busiest shipping lanes. As a result, shipowners/operators face considerable restrictions on allowable discharges for significant portions of their voyages when navigating to, from and through these areas. Vessels wishing to discharge oil from their cargo tanks and bilges in excess of the limits set for special areas must either re-route their course outside of these areas (and face a time and cost penalty for doing so) or contravene MARPOL.

The oil-water discharge requirements of Annex I are detailed in the following table:

Discharge of oil from **cargo tank, pump room and cargo-related areas**	
(**Oil tankers** all sizes)	
Ship’s location	Discharge criteria
Within Annex I Special Areas or Within 50 Nautical Miles (nm) of nearest land (outside Special Areas)	• Any discharge of oil is prohibited • Only clean or segregated Ballast water may be discharged
Outside Annex I Special Areas And More than 50 nm of nearest land	• Discharges of oil and oil-contaminated ballast water are permitted only when the following conditions are met: 1. The tanker must be proceeding en route, and 2. the instantaneous rate of discharge of oil does not exceed 30 litres/nm (an oil discharge at this rate does not produce a visible sheen on the water’s surface), and 3. the total quantity of oil discharged into the sea does not exceed 1/15 000 (for MARPOL existing tankers - built before 1982) or 1/30 000 (for tankers built thereafter) of the total quantity of cargo carried on the previous voyage*, and 4. the tanker has in operation MARPOL-compliant monitoring and control system for the discharge of oil and slop tank arrangements. * However, the requirement that discharged effluent not exceed 15 ppm (see below) means that in reality, operational discharges are limited much below these maximum values).

Discharge of oil from **machinery spaces**	
(**Oil tankers** all sizes and **other ships** of more than 400 GRT)	
Ship's location	Discharge criteria
Within Annex I Special Areas	• The discharge of oil collecting in machinery spaces is only permitted when the following conditions are met: 1. The ship must be proceeding en route, and 2. The oil content of the effluent without dilution does not exceed 15 ppm, and 3. The ship has in operation oil filtering equipment with a 15 ppm monitor and *automatic* stopping device, and 4. bilge water is not mixed with oil cargo residue or cargo pump room bilges (on oil tankers)
Outside Annex I Special Areas	• The discharge of oil collecting in machinery spaces is only permitted when the following conditions are met: 1. The ship must be proceeding en route, and 2. The oil content of the effluent does not exceed 15 ppm, and 3. The ship has in operation oily-water separating or filtering equipment with a 15 ppm, and 4. bilge water is not mixed with oil cargo residue or cargo pump room bilges (on oil tankers)
Ships below 400 GRT (other than oil tankers)	
Ship's location	Discharge criteria
Within Annex I Special Areas	The discharge of oil collecting in machinery spaces is only permitted when the oil content of the effluent without dilution does not exceed 15 ppm.
Outside Annex I Special Areas	The discharge of oil collecting in machinery spaces is only permitted when the Flag State considers that the following conditions are satisfied as far as practical and reasonable: 1. The ship must be proceeding en route, and 2. The oil content of the effluent is less than 15 ppm, and 3. The ship has in operation MARPOL-compliant equipment suitable for ensuring the above.

The cost implications of Annex I discharge criteria

The requirement banning the disposal of fuel sludges at sea leads to one of two costs: the first is the direct cost for disposing of these sludges to a port waste reception facility, the other is the cost to purchase, maintain and operate an incinerator on board.

Oil-water wastes that cannot be discharged according to the Annex I criteria must be held on board and discharged to a port waste reception facility. Port States are required to provide these and ensure that their operation does not impose undue delays on the ship's voyage. However, many states have failed to provide these facilities or effectively facilitate their provision by private operators and port authorities. Furthermore, even when such a facility exists, it may not accept all types of oily wastes (sludge, slop tank oils, etc) and/or may not be available or accessible during the tight schedule many ships must keep to in port. This leads to a situation where ships cannot, or cannot easily, discharge their oily wastes to shore – increasing the incentive for disposing of these wastes at sea.

These facilities are often (although not exclusively) operated by private contractors and tariff levels and structures vary from port to port and from region to region. In some, cases, the waste reception fees are built into the general port fee schedule so that all ships pay regardless of whether they discharge wastes or not ("non special fee"). This has the advantage of removing the incentive for ships to avoid using these facilities in order to reap cost savings. In other cases, the visiting ship must pay a fee based on the volume of waste that it discharges. In these cases, shipowners and operators can realise sometimes-significant savings by not discharging oily wastes to port.

The tables below set out estimated costs for two types of oily waste streams for a representative sample of vessels. The first is for sludges originating from the heavy fuel oil (HFO) used as bunkers. These sludges are stored in a ship's slops tanks, along with oil separated out of bilgewater by the oil-water separator (OWS). In order to reduce the costs of disposal, many ships burn oil from the slops in an on-board incinerator, or in some cases, directly in the engine. The figures below assume that no such equipment is used on board. Furthermore, the table only accounts for the cost of shore disposal of HFO sludges and not slops originating from the OWS and/or cargo tank washings. The latter can be particularly voluminous and increases the costs of shore disposal significantly for tankers. Finally, the table uses figures obtained from Rotterdam, Singapore and ports in the UK. These can be considered in the high range of disposal costs (one industry source communicated the following general Annex I waste reception costs: Asia = approx. USD 80/m^3, North America = approx. USD 115/m^3 and Europe = approx. USD 20/m3). Ships can reduce these significantly by sailing to ports with lower waste reception costs – on condition that the ship's commercial operation and/or charter contract allows for this.

Estimate of representative costs for discharging HFO sludges to port waste reception facilities (prices in EUR)

		Discharge cost following a 30-day voyage			Notional daily cost		
		UK	Rotterdam	Singapore	UK	Rotterdam	Singapore
Tanker	46466 GRT	1800	4708	7468	60	157	249
Bulker	37282 GRT	1375	3595	5703	46	120	190
Container	23691GRT	3780	9885	15680	126	330	523
Dry Cargo	3388 GRT	2991	7822	12408	99	261	414

Using the same ship types and ports, one can calculate the costs of in-port disposal of oily bilge water as follows:

Discharge of all oily bilge water into port reception facility (prices in EUR)

		Discharge cost following a 30-day voyage			Notional daily cost		
		UK	Rotterdam	Singapore	UK	Rotterdam	Singapore
Tanker	46466 GRT	1051	1833	533	35	61	18
Bulker	37282 GRT	843	1470	428	28	49	14
Container	23691GRT	711	1240	361	24	41	12
Dry Cargo	3388 GRT	165	288	84	6	10	3

These costs should be considered as an extreme case, as most ships process their oily bilges onboard. In cases of equipment failure, however, MARPOL normally requires these oily waters to be discharged to land – hence, the estimated costs in the above table can be considered the avoided costs for shipowners and operators who dispose of oily water at sea without going through an operating oily water separating system.

Annex I's discharge criteria require the purchase, operation and maintenance of specific pollution prevention equipment as well the crewing and training of qualified personnel to carry out the prescribed operational procedures. Both of these areas have implications on the operating costs of vessels.

The equipment specifications necessary for compliance with Annex I centre on the oil-water separating system. The main components of this system are:

- A bilge pump.
- An oily-water collection tank.
- An oil-water separating device (OWS).
- Piping into the OWS.
- An overboard discharge pipe out of the OWS connected to an oil content monitor.
- A two-way shut-off valve on the discharge pipe capable of shunting any discharge over 15 ppm. back into the oily water collection tank.
- Piping for extracting oil from the OWS.
- An oil collection/slops tank for oil extracted by the OWS.

Furthermore, the discharge requirements require that piping used for transferring sludge to the slops tank be segregated from the bilge water piping and that the slops tank be fitted with piping and a standard interface for discharging wastes to port reception facilities (or, alternatively, into a homogeniser and/or incinerator if the sludges are to be burned onboard).

The discharge requirements for cargo tank cleanings and oily ballast water from oil and product tankers also have a cost – in particular, the requirement for segregated and/or clean ballast water discharges requires separation of the ballast water and cargo piping and pumping systems as well as the presence of a discharge flow-rate monitor.

OWS costs range from USD 10 000 for a simple parallel plate system to upwards of USD 100 000 for a membrane system with a centrifuge pre-treatment unit. Typically, older ships will have lower-cost systems onboard. Amortised over the OWS's lifetime (which is variable according to the make and level of maintenance), the cost for many of the simpler systems is not that high. However, this equipment – and especially the older and/or more basic units – must be maintained to a high standard. Furthermore, in order to work, they must be operated by knowledgeable and trained personnel. Training in the operation of the OWS system can range from USD 3 000 to USD 5 000 per year – and yet since, strictly speaking, this is not a mandatory requirement, many ship owners may choose to forgo this cost. Furthermore, properly managing the flow and disposal of oily wastes on board, according to one industry source, accounts for 1 person-equivalent per 8 hour watch (composed of both an officer and seafarer). This figure, given for tankers, would be less for other vessels.

Failure to maintain and operate the OWS according to the manufacturer's instructions will likely cause the OWS to fail or to not operate correctly. Proper maintenance of OWS systems includes regular cleaning in order to ensure that the system allows for oils to separate from water. Even "self-cleaning" systems must be periodically checked, washed and have their filters changed. The cost for maintaining an OWS in operating condition depends on the system but can run from USD 3 000 per year and upwards.

Failure to adhere to relatively strict procedures for other daily ship operations can also cause the OWS to fail. For instance, any presence of detergents in the bilgewater can cause thick oily emulsions that not only cannot be treated by most OWS systems but can also foul both the OWS and related piping systems requiring their disassembly and/or flushing. In order to avoid the formation of potentially OWS-clogging emulsions in the bilge, crews should collect machine room wash water and other detergent-containing wash liquids separately or use only specifically formulated "bilge-safe" detergents. Rust, dirt and other common contaminants found in the ship's bilges can also cause the OWS to malfunction.

If the OWS malfunctions, the ship's master must make a note in the Oil Record Book and refrain from discharging oily water to sea unless the ship's safety is compromised. The bilgewater should be discharged to a port waste reception facility at a cost to the shipowner/operator.

Ensuring a properly functioning OWS implies that crews are made aware of the necessary precautions to take when generating bilge water and are properly trained to deal with OWS failure and on-board repair. This type of training should be extended to all crew and not just the seafarers directly responsible for the OWS.

Other elements of the oil-water treatment systems onboard ships also require close attention. The 15 ppm oil content monitor, for instance, must be properly calibrated and maintained. It is not uncommon for this sensitive piece of equipment to malfunction and therefore care must be given to following the manufacturer's maintenance instructions. False readings can generate alarms and automatic shutdown of the OWS discharge valve causing crews to bypass the monitor completely.

When the OWS breaks down, the cost of spares and/or replacement, the cost of shore-side disposal of wastes and the time necessary for crew to repair the system can be significant. During this time oily water cannot be processed and discharged overboard. In some cases, the holding limit of the oily-water collection tank may be reached as bilge water continues to be pumped in. This leads to a situation where the ship's crew will bypass the OWS and directly discharge untreated oily-water overboard. In some cases, shipowners and operators will voluntarily forgo the necessary corrective actions and instruct ship's crews to bypass the OWS thereby reaping cost savings equal to the avoided costs of the repairs for the duration of the period the OWS was not functioning and the avoided costs of discharging the accumulated oily water into a port waste reception facility.

Annex 1. Structural requirement

The second part of Annex I of MARPOL 73/78's approach to reduce the incidence of oil pollution from ships centres on specifying various structural components for ships' hull and ballast systems. These specifications have evolved over time and mainly concern oil and product tankers.

Annex I. Ballast system requirements

Approximately 0.35% of an oil tanker's cargo is left clinging to the walls of it's cargo tanks after discharging. A 150 000-ton Suezmax tanker can therefore potentially discharge 520 tons of oil when emptying ballast water held in product tanks. In order to reduce this type of pollution, MARPOL 73/78 and its subsequent amendments have sought to completely separate ballast from cargo systems in oil and product tankers.

MARPOL violations concerning oily water separators:
Evidence from recent prosecutions

Faced with malfunctioning OWS systems and seeking to avoid the time and cost required to repair, replace and or properly maintain these units, some shipowners, operators and/or crewmembers choose to circumvent the OWS and oil monitor system entirely in order to dump oily wastes directly overboard. Evidence presented in recent criminal proceedings dealing with breaches of MARPOL are instructive as to the methods utilised by crews to circumvent oily water discharge requirements.

Ship's crews will typically use one of two methods to dump oily water directly overboard. The first method involves bypassing the oily water separator entirely by fitting some form of temporary and/or flexible bypass hose from the slops tank and/or bilge pump directly to the overboard discharge manifold. This method requires falsifying the oil record book to indicate that the discharge was processed through the OWS and conjuring some plausible explanation for the malfunction of the15 ppm monitor (which must also be bypassed). The second method involves running the oily wastes through a malfunctioning OWS and tricking the 15 ppm. monitor into registering an allowable concentration of oil in the outflow by purposefully flushing the monitor with clean seawater. While this method does away with the need to explain why the 15 ppm. monitor was malfunctioning, it still requires the crew to falsify oil book entries.

Several port states have increased their scrutiny of OWS and Oil Record books systems in order to apprehend polluters. These inspections have resulted in the indictment and prosecution of a wide range of vessels, masters and companies. In particular, they have highlighted the fact that MARPOL violations are not the sole domain "rustbucket" vessels – several high profile investigations have uncovered suspected OWS bypass pipes in prestigious cruise lines and at least one world-class container operator. In many of these cases, court records reveal that crew and/or operators bypassing OWS systems did so in order to save money.

Selected examples from recent court cases:

Boyang Maritime Kyeong Shin Deep Sea Fisheries Company of Pusan, Korea, Boyang Limited, Trans-Ports International (TPI) and Oswego Limited, 2002, pled guilty to being part of a wide-ranging conspiracy designed to hide routine discharges of oil sludge and oil contaminated bilge waste directly into the ocean from their fleet of ships since at least 1995.

According to the U.S. Justice Department, the companies' fleet of more than a dozen cargo freighters carried thousands of tons of frozen seafood between Alaska and Asian ports. On each journey, the ships dumped as much as 1 000 gallons of oil sludge in U.S. waters.

The companies pled guilty to a 10 count felony information, charging that they worked together to maintain false log books, obstruct justice and tamper with witnesses in order to avoid the spending time, money and other resources to comply with the laws designed to prevent oil pollution from ships (extract from http://www.usdoj.gov/opa/pr/2002/August/02_enrd_487.htm).

Carnival Corporation, 2002, pleaded guilty to falsification of oil record books on several of its ships. The falsifications occurred on numerous occasions between 1996 and 2001, during which period employees ran fresh water past the sensors in the oil water separators of Carnival ships, generating false oil concentration readings. As a result, the sensors failed to activate a diversion valve which would have otherwise kept the contaminated water on board. This allowed the bilge water with oil levels exceeding the allowable limit of 15 ppm to be flushed into sea. Crew members then took the false sensor readings and recorded them in the ships' oil record books (extract from www.usdoj.gov/usao/fls/Carnival.html).

Norwegian Cruise Line Ltd. 2001, Norwegian admitted polluting the ocean in two ways: flushing an oil sensor with fresh water to make contaminated discharges look clean and dumping untreated wastewater overboard. It is unknown how much oil and contaminated water was dumped.

.../...

Until 1998, the SS Norway had a single Oil Water Separator that was referred to by the engineers as "an old piece of junk" Other equipment was used to dump the waste directly overboard. Even after a new and second Oil Water Separator was purchased, ship engineers continued to circumvent the pollution prevention machine until May 2000, when NCL's new owners stopped the practice, according to the factual statement. Ship officers continued to pollute and maintain false records despite the prominent display in the engine room of newspaper articles about the prosecution of Royal Caribbean Cruise Lines Ltd. for similar violations. NCL financially benefited by not expending the resources necessary to maintain its pollution prevention equipment, failing to properly offload waste oil in port and not purchasing adequate equipment in the first place (extract from: www.usdoj.gov/opa/pr/2002/July/02_enrd_441.htm).

Royal Caribbean Cruises Ltd. 1998, RCCL discharged oil contaminated bilge waste, including harmful quantities of oil, from RCCL cruise ships by using equipment and procedures that bypassed the oil water separator. RCCL cruise ships were equipped with bypass pipes that circumvented the oil water separator. Bypass pipes were installed by RCCL and crew members were instructed on their use.

RCCL avoided expenses and commitment of other resources associated with regular maintenance of the oil water separators, replacement of membranes and other spare parts, and offloading of oil contaminated bilge waste in port. Membranes for the oil water separator on some RCCL cruise ships, such as the Sovereign of the Seas, cost approximately USD 10 000 for a single set of membranes (consisting of four membranes). While these membranes were usually changed between zero and one time each year prior to the government's investigation, RCCL now finds it necessary to replace this type of membrane between five and ten times each year per cruise ship using this design. Similarly, where oily bilge waste was offloaded infrequently in port prior to the government's investigation, RCCL now frequently offloads large quantities of bilge waste from some of its cruise ships, including at times more than 100 000 gallons from certain ships each year (extract from: www.usdoj.gov/opa/pr/1998/June/248.htm.html).

Holland America Line, Ltd., 1998, ...the investigation was initiated by an Assistant Engineer on board the SS Rotterdam who refused an order to pump untreated bilge water overboard...Holland America made a conscious decision to defer needed maintenance of the Rotterdam's steering gear, causing the vessel to ship excessive seawater. They then pumped the seawater and oil overboard in knowing violation of the law (extract from: www.usdoj.gov/opa/pr/1998/June/290.htm.html).

Initially MARPOL 73/78 called on tankers to adopt the "load on top" system in which ballast water and clinging cargo were pumped into a designated holding tank. During the ballast voyage, the oil separated from the water that was then pumped from the bottom of the tank and discharged overboard. New ballast and tank washing water was loaded into this tank and the process repeated as necessary. Upon arrival at port, any remaining water was discharged from the bottom and new oil was loaded on top of the residue slops in the holding tank. This had the advantage of allowing cargo owners to retrieve valuable cargo that had previously been flushed to sea.

The "load on top" system institutionalised the use of a segregated "slop" or oily waste holding tank that is still a feature of most ocean-going ships. MARPOL 73/78 however, called on oil and product tankers to adopt a number of other changes to their ballast and product tank washing systems. These are summarised below:

Vessel type and size	Annex I requirements for tank washing and ballast systems
New Vessels (at entry into force date of 1982)	
Oil Tankers over 20 000 DWT	Segregated ballast tanks Crude oil washing System
Product Tankers over 30 000 DWT	Segregated Ballast Tanks
Existing Tankers (at entry into force date of 1982)	
Oil Tankers between 40 000 and 70 000 DWT	Clean ballast tanks*, or Segregated ballast tanks, or Crude oil washing system (*Clean ballast tank must be upgraded to segregated ballast system by 1986)
Oil Tankers over 70 000 DWT	Clean ballast tanks*, or Segregated ballast tanks, or Crude oil washing system (*Clean ballast tank must be upgraded to segregated ballast system by 1984)
Product Tanker over 40 000 DWT	Clean ballast tanks, or Segregated ballast tanks

Crude Oil Washing System (COW): A cargo tank washing system utilising crude oil in lieu of seawater.

Clean Ballast Tank (CBT): A ballast system where one or several existing cargo tanks is designated as a permanent ballast tank. Oil is no longer loaded into the "clean" ballast tank although the "clean" tank still shares pumping and piping arrangements with the cargo system.

Segregated Ballast Tank (SBT): The ballast tanks, pumps and piping are completely separated from the cargo system. Later amendments to Annex I called for the SBT piping to be routed in such a way that it does not enter or cross cargo tanks.

When initially proposed, shipowners strongly lobbied against these requirements as they required significant investments in new, SBT-compliant vessels or expensive retrofitting costs for installing SBT pumping and piping arrangements. At the time, non-compliant owners could expect to reap a benefit by not upgrading and continuing to trade as before although the presence and/or absence of SBT arrangements was and still is easy to detect by Port State inspection officers.

Most crude oil tankers above 20 000 DWT and product tankers above 30 000 DWT delivered since 1983 are equipped with SBTs (see table). However, a considerable number on non-SBT pre-MARPOL tankers are still trading. These tankers normally operate with CBTs but many also still load ballast into non-dedicated cargo tanks (their shared ballast/product pumping arrangements make it possible for shipowners/operators to take on oil in the otherwise designated clean tank which, if undetected and unpunished, increases the revenue-earning potential of the tanker). Given that ships must take on ~25-30% of their deadweight in ballast in order to navigate safely when not loaded, a considerable amount of oily ballast is generated for each return voyage. For example, a 150 000 DWT tanker would in this case produce 37 500 to 45 000 tonnes of oily ballast that must be processed through the OWS and 15 ppm monitoring system. Short ballast voyages and/or any breakdown of the OWS system can lead to a situation where owners must incur the cost of discharging this ballast to a port reception facility and/or face the decision to illegally discharge this waste at sea.

Status of ballast tank arrangements for world tanker fleet in 1999				
	Pre-MARPOL non-SBT tankers		MARPOL SBT or double hull tankers	
	Vessels	DWT (millions)	Vessels	DWT (millions)
Crude oil tanker	594	79.5	1188	159
Product tanker	1756	14.4	3513	28.9

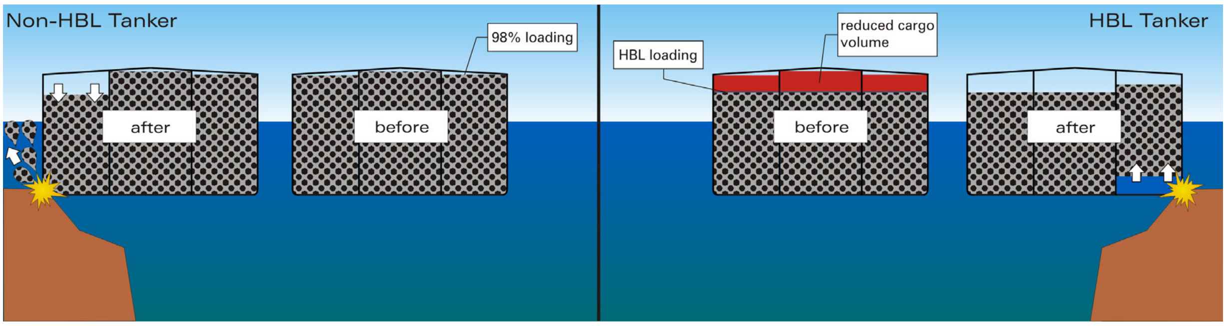
Annex I. Hull requirements

MARPOL 73/78 initially only called for structural changes to be made to ships' ballasting systems despite the calls by a segment of the international community for more stringent hull requirements – and in particular for the phasing out of single hull tankers. Following the Exxon Valdez oil spill, however, and the subsequent unilateral passage of the United States Oil Pollution Act of 1990, the IMO significantly amended Annex I to include double hull construction requirements for new oil tankers. The IMO also agreed to a schedule for the retirement of single-hulled tankers. The 1992 Annex I amendments came into force in 1993 and tankers built after 1994 are all required to have double hulls or an equally effective alternative. It is generally believed that the requirement for double hull construction added 15-20% to the cost of constructing tankers at the time of the requirement. This cost differential, however, has abated with the recent favourable cycle for buyers in the ship construction market.

The phase-out conditions for existing tankers were differentiated according to whether the tanker was built before the passage of MARPOL 73/78 ("pre-MARPOL tankers") or after ("post-MARPOL tankers"). Under an enhanced survey programme, pre-MARPOL tankers were allowed to trade until they were 25 years old at which time they were to be fitted with double hulls or an equivalent alternative arrangement. Once these tankers reach their thirtieth year, they were to be retired from service or fitted with a double hull. Post-MARPOL tankers were allowed to trade until they were 30 years old at which time they were to be retired or fitted with a double hull. The cost of retrofitting an old tanker with a double hull, however, is so prohibitive that 30 year old tankers are typically retired.

Four alternative arrangements to double hull retrofitting were approved for use on pre-MARPOL tankers between their 25th and 30th year. These included the designation of CBT's, the installation of protectively located SBT's covering 30% of the tankers sides or bottoms, the provision of double bottoms or bulkheads to reduce the potential for oil outflows and/or the operation of hydrostatically balanced loading (HBL – see box below). HBL represented a relatively attractive option for shipowners seeking to continue trading after a pre-MARPOL vessel's 25th birthday. HBL, however, requires careful attention by trained crew to detailed operational procedures. Furthermore, requirements for HBL operation are more easily circumvented than the more concrete requirements for double-hulls. Unscrupulous operators could derive a competitive advantage over quality operators by trading 25+ year-old pre-MARPOL tankers without adhering to the strict requirements of HBL. As long as this practice remained undetected, the operator would derive added revenue from the increased carrying capacity of the tanker and save on the costs of training crew and operating the HBL system.

Hydrostatically balanced loading (HBL)



Hydrostatically balanced loading (HBL) relies on the fact that oil is lighter than water and thus floats on its surface. A full cargo tank is filled to approximately 98% of its capacity (to allow for changes in volume and vapour concentrations). In a typical tanker, 98% loading implies that oil is loaded above its natural flotation level -- that is, the pull of gravity is greater than the oil's buoyancy. In such a situation, a bottom grounding will result in an outflow of oil until the level of oil in the tank reaches its natural flotation point -- slightly above the water line. HBL loading calls for less oil to be loaded into the cargo tanks so that the tank levels are slightly below the oil's natural flotation level. This means that a bottom grounding will result in an *inflow* of water rather than an outflow of oil. HBL loading typically means that a tanker must forgo 5-8% of its normal capacity.

In December 1999, the single-hulled product tanker Erica sank in the Atlantic dispersing its cargo on the western shores of France. This prompted a new round of calls for the early phase-out of such vessels. The threat of unilateral action on the part of the European Union led to the rapid amendment of Annex I's single hull phase-out schedule in April of 2002. The crux of the amended schedule (see table below) is that single-hulled tankers will be phased much sooner than previously planned under the 1992 amendments to Annex I. Indeed, all pre-MARPOL non SBT tankers are to be phased out by 2007 and all other single hulled tankers must be retired by 2015 at the latest.

Category	Tanker type	DWT	Cargo	Phase-out
1 [a]	Pre-MARPOL	≥ 20 000	Crude/Dirty oil	2003-2007
	No protectively located/segregated ballast (pre 1981)	≥ 30 000	Oil other than crude/dirty oil	
2 [b]	Post-MARPOL	≥ 20 000	Crude/Dirty oil	2003-2015
	Protectively located/segregate ballast (1982-1996)	≥ 30 000	Oil other than crude/dirty oil	
3	Oil and product tankers under the size limits set in MARPOL	5 ≤dwt ≤ 20 000	Crude/Dirty oil	2003-2015
		5 ≤dwt ≤ 30 000	Oil other than crude/dirty oil	

[a] Category 1 Tankers may trade beyond their 25th anniversary if they either:

- operate with HBL, or
- are fitted with protective wings or double bottom spaces.

Furthermore Category 1 tankers delivered between 1976 and 1981 will only be allowed to reach their maximum phase-out dates if they undergo a more rigorous Condition Assessment Scheme (CAS) is carried out under the responsibility of the Flag State. If they fail the CAS, they must be retired by 2005.

[b] category 2 tankers delivered between 1984 and 1996 will also require to undergo a CAS if they are to reach their maximum permissible lifespan. Otherwise, they must be retired by 2010.

As with the requirements for ballast tank systems, the Annex I requirements for hull structures are relatively straightforward and compliance is generally easily checked through a quick inspection. New ships must be built to these specifications before they can be certified and existing ships must be retrofitted with protective arrangements and have these approved by Flag states and/or class inspections. As with the 1992 amendments, however, it is conceivable that pre-MARPOL non-SBT tankers may still seek to forgo HBL in order to gain more revenue.

Annex II. Control of pollution by noxious liquid substances

The problem: Pollution at sea from ship-borne chemicals

Unlike oil, noxious chemical compounds are not typically generated in the daily operation of a vessel. More often than not, pollution from chemicals at sea comes from the ship's cargo rather than from different technical subsystems of the vessel. Chemicals from the cargo tanks of specialised carriers, however, do make their way into the sea – either through catastrophic hull failures and accidents, through loading and unloading of cargo and/or through cargo tank washing. Annex II concentrates on the latter and sets specific discharge requirements for tank wash water. Unless these criteria are met, this water must be retained onboard and discharged into an appropriate waste reception facility.

Annex II. Regulatory requirements

Certification and record-keeping

Ships carrying noxious liquid substances must be designed and approved for the class of chemicals they are carrying. These ships are required to have an International Pollution Prevention Certificate for the Carriage of Noxious Liquids in Bulk that attest that they meet the conditions necessary for safely handling various non-oil liquid cargoes. The validity of this certificate is conditioned upon an initial survey to ensure compliance with the International Bulk Chemical Code, a periodical survey every five years and an intermediate survey at least every 30 months. These surveys, as in the case of Annex I surveys, are often carried out by class societies.

Certain national regulations call for compliance and certification documents beyond those required by MARPOL. Ship's wishing to trade in these countries must provide these additional documents (*e.g.* the United States requires a United States Coast Guard Letter of Compliance accompanied by additional documentation relating to the cargo and vessel examination).

Ships subject to Annex II must have a "Procedures and Arrangements Manual" (P&A Manual) specifying operational instructions for dealing with noxious chemical cargoes loaded on board. All operations involving the ship's cargo must be made in accordance with the instructions contained in the P&A Manual.

The ship's officers and Master must also update a Cargo Record Book analogous to the Oil Record Book of Annex I. The details of all chemical cargo movements and operations onboard (along with discharges overboard) must be kept in this log and countersigned by the officer in charge. The master must also sign each page.

Finally, the chemical carrier must have onboard an updated Marine Pollution Emergency Plan for Noxious Liquid Substances.

Annex II. Noxious liquid substance discharge requirements

Annex II's discharge requirements are differentiated according to the toxicity of chemicals involved. These are categorised into four classes of substances with decreasing toxicity:

Category	Hazard to human health and/or marine ecosystems	Harm to amenities or other legitimate uses of the sea
A	Major hazard	Serious Harm
B	Hazard	Harm
C	Minor hazard	Minor harm
D	Recognisable hazard	Minimal harm

Discharge requirements are also differentiated according to whether the ship is within an Annex II "special area". These are the Baltic Sea, the Black Sea and Antarctica.

As a general rule, the washing of tanks containing hazardous substances must take place in port and the wash water discharged at a reception facility. Seawater can then be used to rinse the tanks and this rinse water can be discharged overboard as long as the concentration of the cargo is below a set level according to its toxicity and the ship's location. Ships, however, are not required to discharge any pre-wash water into the same port as the discharging port. In these cases, the ship will proceed to a port of its choosing (in many cases the port where it will be receiving its next cargo) and empty its tank(s) of pre-wash water at that location. However, in order to save time and money, some ships could elect to wash out their tanks at sea in contravention to MARPOL Annex II.

The requirements for Annex II discharges are as follows:

<table>
<tr><th>Noxious substance category</th><th colspan="2">Annex II. Discharge requirements</th></tr>
<tr><td></td><td colspan="2">In all areas</td></tr>
<tr><td>A, B, C</td><td colspan="2">The ship must be proceeding en route, and
the vessel must be operating at a minimum speed of 7 knots (self-propelled) or 4 knots (not self-propelled), and
the vessel must be located at least 12 nautical miles from the nearest land, and
discharge must take place below the water line, and
discharge must take place in water at least 25 metres deep (except for category D substances).
- and -</td></tr>
<tr><td></td><td>Outside Annex II Special Areas</td><td>Within Annex II Special Areas</td></tr>
<tr><td>A</td><td>Maximum concentration of effluent after port tank washing is 0.1 % by weight</td><td>Maximum concentration of effluent after port tank washing is 0.05 percent by weight</td></tr>
<tr><td>B</td><td>• Maximum 1 m3 or 1/3 000 of the tank's capacity in m3 can be discharged per tank
• Concentration in the wake astern of the ship is no more than 1 ppm.</td><td>• The tank must be pre-cleaned and the washings stored onboard and/or discharged to a waste reception facility
• Concentration in the wake astern of the ship is no more than 1 ppm.</td></tr>
<tr><td>C</td><td>• Maximum 3 m3 or 1/1 000 of the tank's capacity in m3 can be discharged per tank
• Concentration in the wake astern of the ship is no more than 10 ppm.</td><td>• Maximum 1 m3 or 1/3 000 of the tank's capacity in m3 can be discharged per tank
• Concentration in the wake astern of the ship is no more than 1 ppm.</td></tr>
<tr><td>D</td><td>Maximum one in 10 part dilution of the substance in water.</td><td>Maximum one in 10 part dilution of the substance in water.</td></tr>
</table>

In order to achieve the dilution levels referenced above, the ship's crew must be trained to deal with a wide range of noxious liquid substances and must be completely familiar with the operations outlined in the P&A Manual as mistakes can lead to non-compliant discharges. For instance, if a ship's crew inadequately strips the cargo pipe and pumping system following discharge of a high viscosity substance, the resulting residue can contaminate discharged cargo tank rinse water that would otherwise be MARPOL-compliant.

Complying with Annex II's discharge requirements also implies the presence of functioning discharge recording equipment that can at a minimum record the time, date and flow rate and duration of the discharge. This information can be compared to entries in the Cargo record Book in order to determine compliance. The equipment must be maintained and/or repaired, otherwise, if it fails, rinse water must be kept onboard and discharged into a port waste reception facility.

As with the reception of Annex I wastes, the fees for transferring tank pre-wash water to port waste reception facilities varies from port to port and according to the type of noxious liquid cargo involved. As an example, fees for disposing of these wastes can range from EUR 47/tonne to EUR 155/tonne in the United Kingdom. Furthermore, in many cases, waste contractors will want some assurance of the exact nature of the waste they receive as they might be held liable for disposing of unidentified and/or mis-identified chemical wastes. This might entail paying for tests to ensure that the waste transferred to shore is indeed what the shipowner/operator says it is.

Port pre-washing of tanks containing hazardous substances must be observed by an approved surveyor and, following pre-wash, the cargo piping and pumping systems must be stripped. These requirements entail a cost and/or time penalty that the unscrupulous operator might choose to avoid.

Annex III. Prevention of pollution by harmful substances in packaged form

Annex III of MARPOL 73/78 concerns the identification, labelling and safe stowage onboard of harmful substances in packaged form. It relates to cargo carried by ships and, therefore does not concern ship's stores. Compliance with Annex III's requirements generally falls on the part of the shipper. The principal exception is the responsibility for carriers to develop and follow a plan for the storage of harmful substances in packaged form onboard. As with other ship-board plans (*e.g.* such as the SOPEP), this requires an initial outlay and proper training on the part of the crew in order to adhere to its instructions. The Annex also calls for the ship to have a keep a detailed manifest of dangerous and/or harmful packaged cargoes onboard. Many ports require advance communication of the contents of this manifest.

Compared to the two previous Annexes, compliance costs for Annex III are relatively few minor.

Annex V. Prevention of pollution by garbage from ships

The last of the MARPOL 73/78 annexes currently in force, Annex V seeks to address the other major environmental impact of shipping – the dumping of ships' garbage at sea. While requirements for different waste streams are dealt with separately under this Annex, it should be highlighted that this regulation completely bans the disposal of plastics at sea.

The Problem: Waste disposal at sea

Traditionally ships had relatively simple waste streams consisting of dunnage from packing goods and food wastes from the galley. These wastes were typically dumped of overboard. However, just as land-side waste streams have diversified and grown tremendously in recent years, so too have waste flows from ship-board operations. These now include dunnage, lining and packing (wood and plastic), food and food packing wastes, metal, glass, paper, medical wastes, packaging for cleaning and maintenance compounds, etc. When thrown overboard, this garbage often makes its way to coastlines and/or interferes with marine life. Annex V seeks to regulate these waste streams in order to reduce their impact on marine and coastal ecosystems.

Annex V. Record-keeping requirements

All garbage movements off the ship must be logged into the Garbage Record Book. This record, signed under the responsibility of the Master, allows tracking of the ship's generation and disposal of garbage in order to aid Port State inspectors. A log must be kept of the discharge of garbage to port waste reception facilities, garbage burnt in the incinerator, if present, and/or disposed of overboard in compliance with Annex V's requirements.

Annex V. Waste disposal requirements

The requirements pertaining to the disposal of shipboard garbage, like other discharge requirements, are differentiated according to the whether the ship is in an Annex V "special area" e.g. according to waste type. Annex V special areas are the:

- Mediterranean Sea.
- Baltic Sea.
- Black Sea.
- Red Sea.
- The “Gulfs”.
- Antarctic.
- Caribbean.
- Northwest European Waters.

Annex V's garbage disposal requirements are as follows:

Type of garbage	Disposal requirements	
	Inside Special Areas	Outside of Special Areas
Plastics (includes synthetic ropes, fishing nets, plastic containers, plastic bags, biodegradable plastics, etc)	Disposal at sea prohibited in all areas	
Cargo packing waste Includes floating dunnage, lining and packing materials.	Disposal at sea prohibited	Disposal at sea permitted at least 25 nautical miles from nearest land
Food wastes	Disposal at sea permitted at least 12 nautical miles from nearest land.	Disposal at sea permitted at least 12 nautical miles from nearest land.
Other garbage Includes rags, paper, glass, metal, crockery, etc.	Disposal at sea prohibited	Disposal at sea permitted at least 12 nautical miles from nearest land.
Comminuted/ground food or other wastes.	Disposal at sea prohibited (unless only food and then at least 12 nautical miles from nearest land)	Disposal at sea permitted at least three nautical miles from nearest land.
Incinerator Ash	Disposal at sea prohibited	Disposal at sea prohibited unless ash is free of toxic heavy metal compounds and/or plastic residue and then at least 3 nautical miles from nearest land.

Compliance with the above rules requires that ship waste streams be segregated and treated accordingly. This implies that ship's crews are trained in the handling and disposal of wastes at sea. Space is tight on ships and the accumulation of waste garbage can lead to unhygienic living and/or working conditions. In this context, there is every incentive for ship's crews to dispose of waste quickly. However, their ability to do so in compliance with Annex V is conditioned on the ship being out of a "Special Area" and at some distance from land. Crews must store waste onboard until such time as they can discharge it at sea legally or to a port waste reception facility. In this context, they might be tempted to dump the waste overboard in infringement of MARPOL 73-78. Another option available to them is to compact, shred and/or incinerate the waste onboard in order to reduce its volume.

Annex V does not require ships to have comminutors, compactors, shredders or incinerators but it does set performance standards for these when they are present. This waste processing machinery provides shipowners/operators with more flexible options for storing and disposing of waste onboard and can save money by reducing port waste reception fees. Incinerators also serve a dual purpose in that they can also be used to burn oil residues and sludges rather than paying for their disposal in port. Costs for incinerators vary according to capacity and size but a typical unit can cost in the order of EUR 60 000.

As with other waste-processing equipment on board, these devices can and do break down. Accordingly they require a certain level of maintenance. If the machinery breaks down, ship's crews may be tempted to dump wastes illegally overboard rather than storing them onboard and or disposing of them in compliance with Annex V's requirements. Until repairs are made, shipowners/operators save on the required repair costs and the avoided waste disposal fees, just as they might have saved on necessary maintenance costs beforehand. In practice, however this would entail the falsification of the garbage record book, and Port State authorities are likely to detect discrepancies, especially if they are suspicious about the low quantity of garbage carried on board.

Annexes not yet entered into force

Annex IV and VI of MARPOL 73-78 have yet to come into force. Shipowners who choose to comply with their requirements might put themselves at a competitive disadvantage (if only costs are considered) and shipowners not implementing these requirements may gain a competitive cost advantage. However, the competitive outcomes of following the rules contained in Annex IV and Annex VI do not stem from non-compliance as such. Therefore the competitive advantage/dis-advantage is not unfairly or illegally gained – at least until the instruments come into force.

It is important, however, to look at some of the cost implications of the requirements of these Annexes as they will eventually come into force. At that time, shipowners will be required to abide by them and unscrupulous owners will be able to derive unfair cost savings by not complying.

Annex IV. Prevention of pollution by sewage from ships

Annex IV aims to reduce the sanitary risk from "black water" (discharges containing human, animal and/or medical wastes). Many States have local requirements regarding these discharges as well, especially as Annex IV has yet to come into force. As with other MARPOL 73/78 Annexes, the rules call for both certification and operational/equipment requirements.

Annex IV. Certification requirements

In order to comply with Annex IV, ships must be issued an International Sewage Pollution Certificate. Renewal of this certificate is conditional upon a periodical survey of the ship's sanitation systems and piping every five years.

Annex IV. Sewage discharge requirements

Ships have three options for discharging their black water according to the type and level of pre-treatment applied. The requirements for sewage discharge are as follows:

Annex IV. Sewage discharge requirements		
Untreated	Comminuted and disinfected	Treated
• Sewage must be retained in holding tanks, and, • Discharge must take place at least **12 nautical miles** from the nearest land, and • The discharge rate must be approved by the Flag State, and • The ship is proceeding en route at a minimum speed of four knots.	• Discharge must take place at least **4 nautical miles** from the nearest land, and • The equipment must be MARPOL-compliant and approved by the Flag State, and • The ship is proceeding en route at a minimum speed of four knots.	• The treatment plant must be MARPOL-compliant and approved by the Flag State, and • There are no floating solids and/or discoloration surrounding the discharge.

If these requirements cannot be met (*e.g.* a ship with no treatment facilities navigating within 12 nm of shore and/or at quay), then sewage waste must be held on board and transferred to a port waste reception facility. The cost advantages that could eventually be derived from non-compliance include the savings from avoided port waste fees (*e.g.* EUR 23/tonne in the United Kingdom), avoided capital costs associated with the sewage processing facilities and/or maintenance and repair costs for the equipment.

Annex VI: Prevention of Air Pollution from Ships

The text of Annex VI, agreed at the IMO in 1997, details measures to reduce the emissions of sulphur and nitrogen oxides from ships. It also stipulates actions to be taken to reduce the use and emission of ozone-depleting substances and other harmful air emissions.

This Annex calls for the sulphur content of marine bunkers to be capped at 4.5 % world-wide. In addition, it defines "SOx Emission Control Areas" (ECA – currently the Baltic and North Sea) where the sulphur content should not exceed 1.5%.

All Marine propulsion systems installed on ships constructed after January 2000 or engines having undergone a major conversion after that date will have to comply with the Annex's NOx Technical Code which calls for significant reductions in NOx emissions.

Annex VI. Certification and record-keeping requirements

Ships will be required to hold an International Air Pollution Prevention Certificate that will be issued by the Flag State or its representative upon an initial survey. This survey is to be followed up by a periodical survey at least once every five years and by an intermediate survey every 30 months.

In addition, ship's will be required to retain bunker delivery notes onboard for a period of three years and fuel oil samples for at least one year following delivery.

Annex VI. Emission and operational requirements

Meeting the world-wide sulphur content restriction of 4.5% is a relatively easy task – especially as bunkers today have an average sulphur content of 2.7%. However, ships sailing in ECA's will have to ensure that the fuel they burn meets the lower requirement of 1.5%. Low sulphur bunkers are typically more expensive since their processing is more time- and energy-consuming although the volatile nature of bunker markets makes an exact estimation of the sur-cost of low sulphur fuel difficult. Generally, this value seems to be approximately 20-30% above of the cost of regular bunkers – approximately EUR 32 per tonne. Given limited refinery capacity for low-sulphur bunkers, however, an increase in demand for these fuels might push these prices up until new refining capacity comes on-line.

Meeting the low-sulphur bunker requirement for ECA's will also require ships to either fill up completely with low-sulphur bunkers before their arrival into the ECA – a highly unlikely outcome given the need to empty the tank of existing high sulphur bunkers and the added cost of steaming with low-sulphur fuels – or have a dual fuel system onboard. While this is not necessarily a problem on newly built (or on some older ships that were designed to use marine diesel oil for manoeuvring in ports), retrofitting existing ships with such a system will prove expensive. Another option afforded shipowners/operators by Annex VI is the installation of flue seawater scrubbers to reduce the sulphur content of exhaust emissions to below 6 g. Sox/kW h. This is an expensive option as well and precludes the use of the system in ports given the high acidity of the scrubber discharges.

The NOx Technical Code of Annex VI calls for an important reduction in NOx emissions from new and/or refitted engines. This reduction can be obtained through one of three methods: by using gas turbines in place of heavy fuel oil (HFO) engines, by fitting current engines with exhaust catalysts or by modifying the combustion properties of existing engines.

The first two solutions allow for reductions in NOx of up to 95% but involve significant costs. Modifying the temperature of the combustion chamber (and thus the formation of NOx) seems a more promising and lower-cost alternative at present. However, this strategy can reduce the efficiency of the engine and slightly increases the amount of fuel necessary to achieve the same performance as before. The options available to reduce NOx from HFO combustion to within Annex VI's criteria are summarised below:

NOx reduction method	Description	Potential reduction	Investment costs (base 1999) in EUR
Emulsification	The engine runs on an emulsion of water and fuel. This leads to a 10% reduction of NOx per 10% of water present in the emulsion. Fuel consumption can increase by 1% for every 10% of water content.	20-40% reduction	~30 300 (for engines less than 3 MW)
Humidification (fumigation)	Cooled moist air added to the combustion exhaust can reduce NOx significantly	50-80% reduction	Unknown
Direct injection	Water or other liquids are injected directly into the combustion chamber.	50-60% reduction	From 9 000 to 26 700
Selective catalytic reduction	Using a catalyst results in the highest reductions of NOx. Requires low sulphur fuel (<2%) and other consumables (urea and replacement of catalyst material).	85-90% reduction	36 to 61 per kW for engines over 1000 kW 61 to 182 per kW for engines under 1000 kW Running costs included
Engine tuning and injection retardation	Reducing the exhaust temperature and/or retarding the start of the oil fuel injection, NOx reductions can be achieved at very low costs – albeit with a fuel efficiency penalty.	10-30%	Low cost

International Convention on the Control of Harmful Anti-fouling Systems on Ships

Ship's hulls attract all kinds of shellfish and algae colonies. As these grow and spread, they can have an impact on the operating efficiency of the vessel. In particular, the increased drag caused by these organisms can impose a significant fuel-efficiency penalty. For this reason, ships were regularly rid of these organisms through dry-dock or underwater cleaning. The advent of paints containing organotin biocides, (and Tributyltin – TBT – in particular) in the 1970's however, obviated the need for these frequent and expensive cleanings. Ships painted with TBT could go as long as five years between hull paintings with little significant fouling. The longevity of these compounds, however, combined with their release into the water through normal wear, resulted in a significant ecological hazard for marine ecosystems.

Recognising TBT as a danger to marine ecosystems in 1989, the IMO agreed to ban these compounds in a International Convention agreed in 2001. This Convention calls for a complete ban of the use of organotin biocides for ships painted or repainted starting in 2003. Ships painted on or after 2003 will have to have a International Anti-fouling System Certificate onboard that will be issued after an initial survey. This certificate will be renewed following another survey each time the ship is repainted.

The Convention also calls for all ships hulls to be free of organotin-based antifouling paints, or to have these sealed in such a way as to avoid leaching by 2008.

Some countries, such as Japan, have banned TBT for over a decade and have built up considerable experience with tin-free compounds, as have certain commercial operators who have experimented with these paints before the IMO ban. Their experiences, however, have been mixed. Tin-free anti-fouling paints have typically been more expensive that TBT paints. They also have tended to be less effective, requiring more frequent applications and/or hull cleanings. While paint suppliers are making advances in providing equally effective and durable non-tin paints, shipowners/operators must still bear this cost differential. These costs include the cost of purchasing and applying the paints, undertaking more frequent hull cleanings, lost trading revenue while ships are painted/cleaned and a fuel consumption penalty for steaming with fouled hulls.

According to figures from Sea-Land Corporation, these additional costs were estimated to be approximately USD 200 000-USD 270 000 per vessel (container carrier) per five year dry dock cycle (or USD 110-USD 148/day). These costs include regular hull cleanings every six months after 2.5 years and additional fuel costs due to hull fouling. While some companies claim equal performance from non-TBT anti-fouling paints, most commercially available TBT-free coatings have an effective life of 2.5 to three years. For shipowners wishing to remain on a five-year dry dock cycle, this entails the added cost of regular hull cleanings. Alternatively, these ships must be dry-docked and re-painted at shorter intervals and considerable cost to the owner. However, the shorter life of non-TBT coatings might not pose a significant problem for ships on a tighter dry dock schedule (*e.g.* many older ships and heavy use vessels such as ferries) – although the higher cost of TBT-alternatives still remains an issue.

It is likely that the development of commercially viable TBT-free anti-fouling coatings will accelerate as demand increases, thus the cost premium associated with tin-free paints will probably decrease in the future. Already, some shipping companies and paint providers claim five-year intervals for non-TBT paints. Furthermore, the development of unmanned remote hull-cleaning technologies will also contribute to lowering the costs of using non-TBT paints.

However, the cost differential remains and could be unfairly used by a substandard operator to gain an advantage over a competitor complying with the TBT ban. The savings for the non-complying operator would be substantial, yet the risk of discovery would likely be high as such a strategy would require the shipowner to obtain fraudulent compliance documents and would involve the co-operation of a willing paint contractor, dry-dock facility and (possibly) certification officer – and would be detectable through a hull paint sample test.

Draft International Ballast Water Convention

The problem: Organisms in ballast water

Coastal states have always faced the problems caused by the spread of non-native organisms carried by ships. These plants and animals typically were carried on the ship’s hull and introduced into new ecosystems where in many cases, spurred by the absence of natural predators, they spread rapidly and caused significant harm to local ecosystems and economies. Now, these organisms are primarily spread through the discharge in arrival ports of ballast water loaded in departure regions. The damage caused by these organisms can be tremendous – running into the millions of dollars for regional contaminations such as that caused by the Zebra Mussel in North America or by the *Caulerpa taxifolia* algae in the Mediterranean. The IMO has recognised that the presence of parasitic organisms in ships’ ballast waters poses a serious threat and has commenced work on a draft convention to address the issue.

Options for reducing the risk from parasitic organisms in ballast water

There are three major categories of ballast treatment options: chemical, mechanical and/or physical.

Chemical methods for ballast water decontamination involve changing the physical properties of the water taken on board to kill unwanted organisms. Many of these options tend to be potentially expensive to put in place and operate, given the relatively large amounts of chemicals necessary and the cost of treating chemical residues in the clean ballast.

Mechanical technologies involve separating contaminating organisms from the ship's ballast water or removing contaminated ballast water from the ship. The former typically involves running ballast waters through filtration and/or separation systems in order to reduce the number of contaminating organisms. These are generally considered to be lower cost options than those enumerated above but are equally considered to less effective. Problems include filter clogging, space requirements, disposal of residues and the problem that these systems experience in removing very small marine organisms.

Removing ballast waters from the ship, however, is increasingly seen as one of the principal methods for treating ballast waters. This operation can involve the discharge of ballast water to port reception facilities (with all of the problems that this might entail as seen in the case of Annex I wastes) or by exchanging ballast water at sea. The latter can be accomplished by sequentially emptying and refilling ballast tanks at sea or by running fresh seawater through the ballasts until these are fully renewed. Both of these are relatively low cost options compared to the chemical treatments but pose problems as they can compromise the stability of the ship in certain conditions and/or lead to lost trading time as the ship reduces speed or stops to exchange ballast water. These mechanical options also do not address the risks posed by organisms present in the sludges that remain after ballast water exchanges.

Finally, several physical techniques have been considered for the treatment of ballast water. Of these, ultra-violet radiation and ballast water heating have shown the most promise. As with other potential treatments, however, many of these technologies remain experimental and have yet to be fully tested at the scale required for ballast applications. The table below provides an early assessment of the costs of a selection of ballast water treatments:

Method	Description	Technical efficiency	Cost EUR/m³	Cost EUR/day (30 days) 150000 DWT tanker	Cost EUR/day (30 days) 80000 DWT container vessel	Cost EUR/day (30 days) 40000 DWT bulk vessel
Open ocean ballast water exchange	Currently the main option for ballast water management. Rigby said this was the cheapest but poses a very serious risk of excessive organism invasion.	95-99% water replacement	.022	29	18	12
Heating with ballast water tank flushing/exchange	Technology uses heat from the ship (or another source) to heat the water in the tanks to temperatures that would kill nuisance organisms.	Could be close to 100%	.034 w/o flushing .055 w/flushing	44 w/o flushing 72 w/ flushing	27 w/o flushing 44 w/ flushing	19 w/o flushing 30 w/ flushing
Filtration	Using a filter system to strain out nuisance species. Efficiency varies by screen diameter in microns.	82-95% at 50 microns 74-94% at 25 microns	.071 to .194	92 to 252	57 to 155	39 to 106
Chemicals	Types include hypochlorite (chlorine), hydrogen peroxide, ozone and others.	Variable	.145 to 24.3	189 to 31590	116 to 19440	79 to 13284
Ultra violet (UV) radiation	Irradiating the ballast water with UV radiation requires pre-filtration.	Ineffective for certain organisms	.17 to .511 w/ filtration	221 to 664	136 to 409	93 to 279

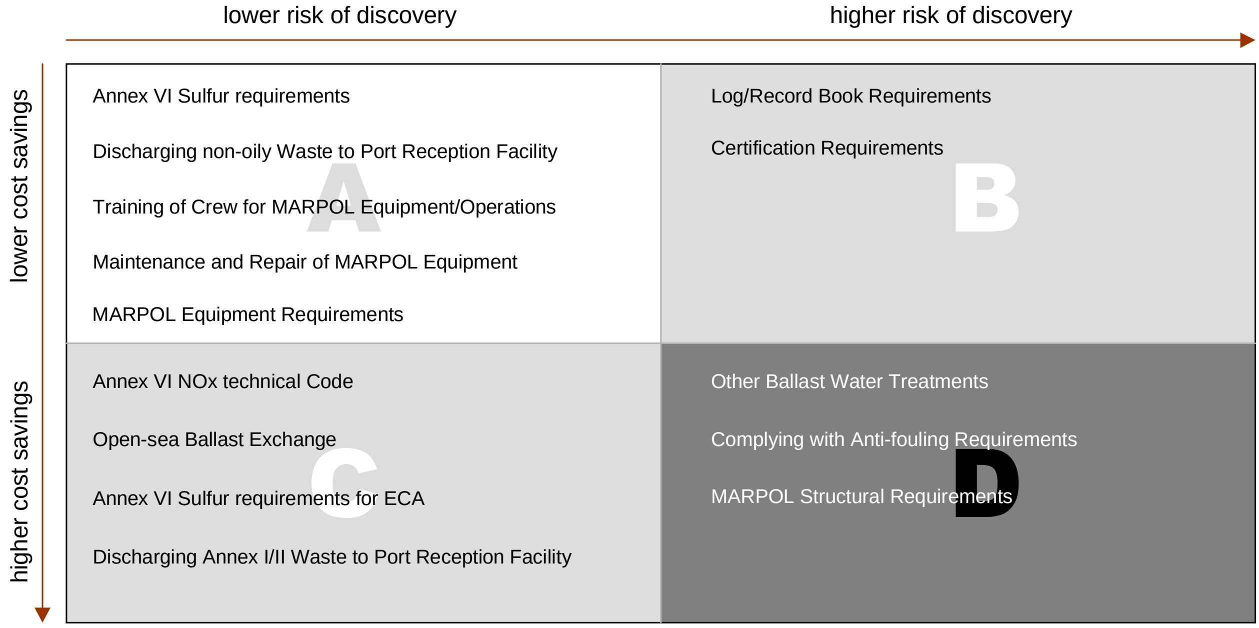
Source: Adapted from http://www.cqdjournal.com/Hot_Events/ballast-imo/ballast-tech/ballast-tech.htm (May 3, 2002).

Despite the uncertainties surrounding ballast water treatment options, the Draft Ballast Water Convention has started to take form. This Convention will be shaped on the conviction that ballast water treatment systems will, in the future, have to be part of the fundamental design issues addressed by shipbuilders. Ballast tanks and ballast systems will have to be designed in such a way as to reduce the risk of contamination by invasive species. This will likely imply the imposition of operational ballast water plans, logging requirements and mechanical recording devices as for many of the MARPOL annexes. This will also mean that when ships are designed for open water ballast exchanges, they must be built in such a way as to resist the stresses this method imposes. These requirements will impose costs on top of those highlighted in the above table.

Costs and risks of non-compliance

As can be seen in the previous sections, there are a number of cost considerations inherent in international environmental regulations.

The figure below illustrates the relative costs and risks of non-compliance with different elements of the body of international environmental regulations governing shipping. These are only intended to convey the relative orders of magnitude as actual costs and risks vary tremendously according to ship type, age, trading pattern, flag state and port state administrations.



While the cost implications of MARPOL's structural requirements (*e.g.* for ballast tank systems and/or double hulls for tankers) are considerable, non-compliance with these is relatively easy to detect and shipowners/operators will likely not seek cost savings by disobeying these regulations. Certification, likewise, is relatively easy to verify and shipowners/operators are likely to forgo these requirements.

The operational aspects related to complying with MARPOL and its related instruments represent a much easier target for non-compliance. Especially as many of these can be bypassed with a relatively low risk of discovery. Furthermore, these requirements are such that they can be followed in some instances, (*e.g.* not dumping plastics-containing incinerator ash before going to a port with strong Port State Control inspections), and not in others. This possibility of occasional non-compliance allows substandard owners and/operators to save money by disregarding these rules when the risks are the lowest or the costs are the greatest (*e.g.* dumping oily sludge overboard before going into a port with high waste reception fees).

It might be anticipated that substandard operators would contemplate savings from non-compliance measures in boxes A and C of the above figure. While owner/operators who regularly contravene regulations in these boxes are relatively few, one can expect that some borderline operators might be tempted to achieve savings in these areas in tight market conditions – if only occasionally.

Generally the operational costs related to environmental compliance can be separate into four broad categories:

1. The costs associated with ship's equipment for processing, reducing, storing and disposing of waste.

2. The costs of regularly maintaining this equipment.

3. The costs of waste disposal to port waste reception facilities.

4. The cost of staffing training and educating ship's crews to comply with these regulations.

However, gaining insight into which strategies unscrupulous shipowners and operators use to requires information on the typical patterns of non-compliance with international regulations.

Evaluating non compliance with environmental regulations

Characterising the cost savings realised by substandard shipowners/operators requires a detailed understanding of common and substandard practices intended to avoid compliance with international environmental regulations. This insight, for obvious reasons, is notoriously difficult to obtain from substandard shipowners/operators themselves. Fortunately, the IMO rules allow for a detailed inspection regime that sheds light on current practices in the maritime sector.

Flag States and Port States share responsibility for compliance with the IMO's rules. Flag States have primary responsibility for ensuring this compliance and must certify that ships flying their flag are operating in conformity with international environmental regulations. Port states, on the other hand, have the right to ensure that vessels entering their ports do indeed comply with this regime before they are allowed to sail. Of the two, Port States have the greatest incentive to ensure this compliance given that any pollution stemming from non-compliance will impact them foremost. In many instances, Port State inspections provide the best insight into actual compliance practices amongst shipowners/operators since these typically occur much more frequently than Flag State inspections. Data on these is relatively easy to come by, at least for many OECD member countries.

Another source of data on compliance is the result of private vetting inspections undertaken by commercial charterers. These inspections, common in the oil trade, allow charterers to ensure that the ships they use meet their standards for safety and environmental performance. Data from these inspections is relatively harder to come by, however.

Furthermore, not all ships entering ports are inspected. Inspection rates vary from country to country and from region to region. Among the member countries of the Tokyo Memorandum of Understanding on Port State Control (Tokyo MOU – covering much of the Asia-Pacific area), approximately 65% of all individual ship visits were inspected by authorities. Within the Paris MOU area, 28.6% of visiting ships were inspected.

The possibility that no inspection will occur might lead certain shipowners/operators to gamble that non-compliance with MARPOL 73-78 requirements might go undetected. Port State Control authorities realise this and periodically organise targeted inspection campaigns. These tend to reveal that some MARPOL violations typically go undetected during normal inspections. Port State authorities also seek to increase their chances of uncovering non-compliant vessels by developing targeting matrices. These define boarding criteria based on the type of vessel, Flag State, class society, past history and vessel age in order to ensure that vessels with the greatest history/potential for non-compliance are caught.

A slight majority of ships boarded display some sort of deficiency. In 2000, 61.79% of vessel inspections in the Paris and Tokyo MOU areas uncovered violations of international maritime regulations. Many of these deficiencies were relatively minor and did not lead to the detention of the ship[3]. The fact that these deficiencies were rectified in port during the scheduled stop does not necessarily mean that a significant breach of international regulations did not occur. For instance, inspectors might find that the Oil Record Book of a visiting ship was improperly filled out and that the 15 ppm oily water discharge monitor was malfunctioning. These two deficiencies can be relatively quickly rectified in port and would not lead to the detention of the vessel. However, the vessel might have illegally discharged much of its oily bilgewater into the sea in contravention of Annex I of MARPOL 73-78. Hence, while the deficiencies in this hypothetical case were not grounds for detention, they do not preclude the fact the vessel had acted illegally – and saved money by doing so (*e.g.* by not paying for the discharge of its oily bilgewater to a port reception facility). This said, however, even conscientious owners may have discrepancies discovered

[3] In 2001, the Paris and Tokyo MOU's reported detention rates of 9.9 and 7.7 % respectively.

during their ships' inspections. The existence of deficiencies on a ship should therefore not be considered as prima facie evidence of a substandard operation.

Port state control inspections, deficiencies uncovered and detentions
2000, Paris MOU and Tokyo MOU areas.

	Inspections	Inspections w/ deficiencies	% Inspections w/ deficiencies	Detentions	% Detentions
Bulk carriers	8 776	5 153	58.72%	598	6.81%
Chemical carriers	1 481	785	53.00%	92	6.21%
Gas carriers	616	276	44.81%	20	3.25%
General dry cargo	12 793	9 079	70.97%	1 593	12.45%
Passenger ships/ferries	861	473	54.94%	43	4.99%
Refrigerated cargo	1 269	767	60.44%	92	7.25%
Container-ro-ro-vehicle carrier	5 108	2 906	56.89%	203	3.97%
Tankers combined carriers	2 786	1 418	50.90%	196	7.04%
Other types	903	517	57.25%	28	3.10%
Total	**34 593**	**21 374**	**61.79%**	**2865**	**8.28%**

As can be seen in the above table, gas and chemical carriers display the lowest rates of deficiencies and, along with container, roll on-roll off and vehicle carriers, share the lowest detention rates. General dry cargo vessels on the other hand, have deficiency and detention rates much higher than average. These ships earn low freight rates, have extremely tight operating budgets and are likely to be tempted to seek cost savings whenever possible and in some instances, illegally.

The Paris and Tokyo MOU members also keep data on the various types of deficiencies encountered. These show that, overall most deficiencies uncovered during Port State inspections are not related to environmental regulations. Only 8% of all deficiencies discovered during recent Paris and Tokyo MOU inspections are categorised as MARPOL-related and an additional 5% relate to ship's certification and documentation which includes environmental certification (*e.g.* the International Oil Pollution Prevention Certificate). However, closer analysis of the Paris MOU data reveals that the ratio of MARPOL-related deficiencies to individual ships is much higher – as high as 43% concerning Annex I violations. This last figure is troubling as almost half of all vessels inspected by Paris MOU members revealed some violation of Annex I.

While exact figures on MARPOL compliance – *e.g.* figures that separate out minor deficiencies from those signalling breaches of MARPOL – are difficult to come about, one study estimated non-compliance rates for Annex I of MARPOL to average approximately 13% internationally, adjusted for the composition of the world fleet (United States National Academy of Sciences , "Oil in the Sea III: Inputs, Fates and Effects (2002)"). In this study, compliance rates ranged from 99% for large new tankers to 85% for commercial non tanker vessels.

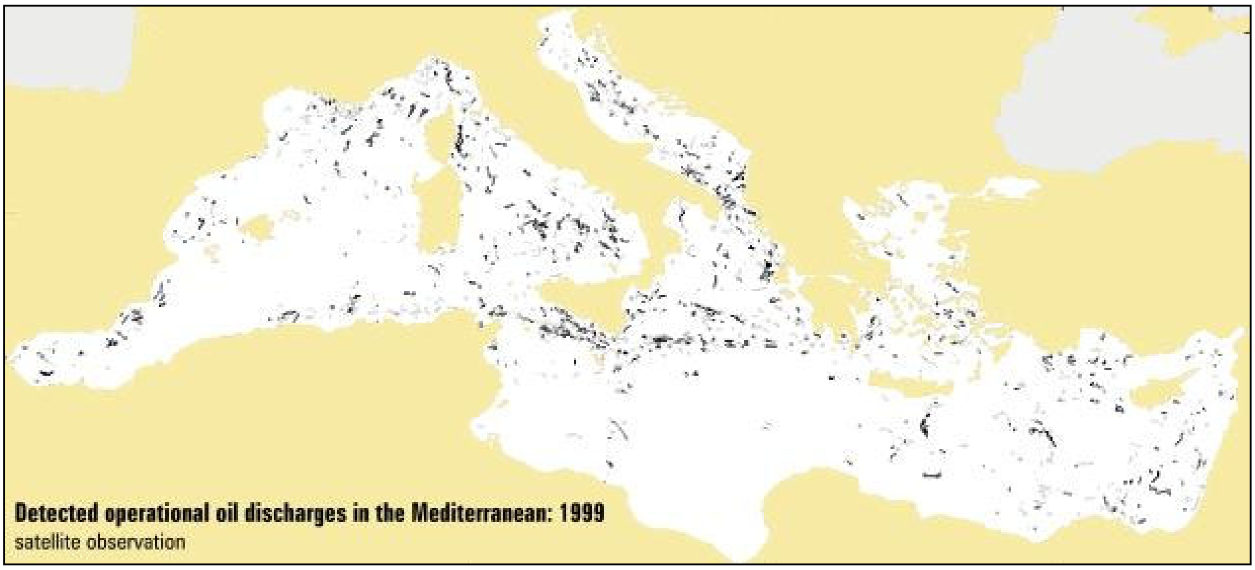
The Paris MOU's data for 2000 provides more detailed insight into the exact nature of MARPOL violations.

Deficiencies discovered during Paris MOU Port State inspections in 2000				
	Annex I	67%	Oil Pollution Prevention (IOPP)	879
			MARPOL – SOPEP	1012
			Oil Record Book	1441
			Control of Discharge of Oil	160
			Retention of Oil on Board	418
			Segregation of Oil and Ballast	9
			Oil Filtering Equipment	780
			Pumping Discharge Arrangements	80
			Oil Discharge Monitoring and Control System	112
			15 ppm Alarm Arrangements	340
			Oil/Water Interface Detector	8
			Standard Discharge Connection	55
			Ballast Arrangements: SBT/CBT/COW	16
			Pollution Report - Annex I	14
			Ship Type and Designation - Annex I	3
			Suspected of Discharge Violation	48
			Oil-Oily Mixtures in Machinery Spaces	118
			Other Annex I	379
	Annex II	1%	Certificate Pollution Prevention Noxious Liquid Substances	8
			Cargo Record Book	19
			P&A Manual	12
			Residue from Discharge Systems	2
			Tankwashing Equipment	4
			Cargo Heating Systems for Cat. B Substances	7
			Ventilation Procedures/Equipment	8
			Pollution Report - Annex II	2
			Loading/unloading/cleaning Cargo tanks	6
			Other Marpol Annex II	17
	Ann. III	.5%	Marking and Labeling	4
			Documentation	6
			Stowage	12
			Other Annex III	9
	Annex V	13%	Placards	94
			Garbage Management Plan	364
			Garbage Record Book	251
			Garbage	422
			Other Annex V	33
	Other	19%	Other Marpol Operations	72
			Ballast Fuel and Other Tanks	290
			Cleanliness of Engine Room	1218
			Bilge Pumping Arrangements	118

This table reveals that the overwhelming majority of MARPOL violations discovered during port State inspections concern principally Annex I (Oil) and, to a lesser extent, Annex V (Waste) of the Convention.

Annex I. Violations

That pollution from ship operations is still a problem is no surprise. Despite tremendous reductions in the amount of oil released to the sea, some ships continue to dump cargo, fuel or bilge oil and sludge illegally. The figure below illustrates the frequency of oil discharges in the Mediterranean captured by satellite in 1999. This image is telling – especially as the Mediterranean is a MARPOL Annex I "Special Area" where no visible discharges of oil are allowed. Other satellite and aerial surveillance campaigns of the Baltic, North Sea and Southeast Asia reveal similar pictures. The truth is that even though a small *percentage* of ships contravene Annex I, an unacceptable number of vessels continue to discharge oil to the sea in relative impunity.



Source: EU DG-SRC (IPSC) "Oil spill statistics in the Mediterranean Sea", ERS 1/2 remote sensing data.

Not all ships discharging oil to the sea in violation of Annex I do so illegally, and not all ships discharging illegally share the same motivations. In the normal operation of a ship, accidental discharges of oil can occur, although on a well-run ship with a proper safety and environmental management system, this should be a relatively rare occurrence.

Other vessels will discharge oil knowingly because they cannot discharge to land. For example, a tanker sailing between areas where few adequate oily water waste reception facilities exist (*e.g.* in the Gulfs area) and offshore reception terminals (where no discharge facilities exist) can soon find itself with full slops tanks. The master can either sail for a port with reception facilities despite the loss in time, money and likely breach of charter contract, or discharge at sea. This last point is an important one because many charter contracts contain terms that, when combined with the lack of waste reception facilities, put pressure on masters to discharge slops at sea. For example, charter contracts calling for the use of the “full capacity” of the tanker means that the slop tanks must be empty at the start of the charter. One possible solution is to load cargo on top of the slops but few charterers accept this. An alternative solution is for the ship to empty its tanks at sea (if port waste reception facilities are not available).

The inadequacy of port waste reception facilities is a significant contributing factor to Annex I violations. Incidents such as the voyage of a tanker forced to conserve slops on board for three months described below are, unfortunately, still relatively commonplace in many parts of the world and show the difficulty some ship owners face when seeking to comply with Annex I:

Highlights from a three month tanker voyage in late 2000:

Jubail: *Port refused to receive slops.*

Bahrein: *Port slop discharge connection blocked due to coagulation (not the first time this has happened) – no discharge of slops.*

Koweit: *Berthing denied because the master requested to discharge slops before loading. The ensuing conversation with the Port Captain revealed that the small oily waste reception facility was built "just to satisfy the IMO", that the installation had not worked in the past three months, that the port authority had no intention to repair the facility, that anyway, ships coming to load in Kuwait knew to arrive with no slops on board and that whatever ships did with slops prior to arriving in Kuwait was not the Port Authority's problem – which goes far to explains why the sea was covered in oil four to five hours outside of this zone.*

Ulsan: *Port refused to take slops.*

Sri Racha: *Lack of adequate reception facilities at loading terminal.*

Singapore: *Lack of adequate reception facilities at unloading terminal (the master finally arranged for a barge to receive the contents of the slop tanks – although this operation was undertaken in dangerous conditions) (AFCA N, 2001).*

Some ships might also contemplate discharging oily wastes to sea wilfully despite the existence of adequate reception facilities. The principal motivation for such discharges is to avoid paying the fee for receiving oily wastes ashore and/or face the loss of time necessary for disposing of Annex I wastes appropriately.

Under-maintenance, under-manning and postponement of repairs for OWS systems and/or incinerators can lead to a situation where ships that previously had the capacity to treat oily wastes and oily water on-board can no longer do so and may choose to discharge these overboard rather than pay for their proper land-side reception. Evidence from the prosecution of oil pollution court cases reveal that OWS and/or 15 ppm oil monitor bypass pipes have been found on all types of ships, from decrepit cargoes to prestigious cruise ships.

Maintenance costs on vessels typically rise more quickly as vessels age while charter costs typically decrease. In general, these costs are significant given that repairs and maintenance represent the second largest operating cost after manning. Owners must make a determination as to the amount of maintenance they feel is worthwhile given the slowly dwindling trading life of the vessel. The index of maintenance costs in the table below highlights that past a ship's 20^{th} birthday, some owners may feel that high maintenance/repair outlays are no longer worthwhile and these decrease markedly. From the perspective of environmental compliance costs, this means that ships most able to pollute (fewer SBT tankers, fewer modern OWS, fewer incinerators, etc) are often not maintained in such a way as to avoid MARPOL infractions.

Index of maintenance and repair costs with ship’s age (ship class 5-9 years-old = 100)		
Age	Scheduled maintenance/repairs	Unscheduled repairs
0-4	80	40
5-9 *	100	100
10-14	125	175
15-20	160	200
+ than 20	200	135

Source : Drewry Shipping Consultants.

Shipowners and operators are free to determine the level of maintenance they wish to keep for their ships. Low maintenance in itself is not a violation of international maritime rules and is often used as a cost-saving strategy in tight market conditions. Low maintenance, however, can lead to equipment breakdowns which then imply much higher compliance costs. These may be avoided by unscrupulous operators by postponing repairs and disposing of oil waste at sea. Thus, while the first-order costs of Annex I operational procedures are not that great, the second-order costs to shipowners and operators are significantly higher. Avoiding these provides the non-compliant owner/operator with an advantage over a competitor that spends more on maintenance, repairs, stores, manning and waste disposal.

Illustrative examples

Precisely determining the aggregate cost savings accrued through non-compliance with international environmental regulations is a difficult task. The rules are complex, refer to numerous specific sizes and classes of vessels, span a wide range of environmental media and non-compliance strategies vary enormously. Many operators who keep specific track of these costs are hesitant to share this information because of its commercial sensitivity. Others simply do not have in place systems for monitoring their environmental compliance costs per se. In this context, it may be worthwhile to examine some specific examples to gain insight into the nature and scope of the cost savings achieved by non-compliant operators.

The following table illustrates three representative environmental compliance budgets for a container vessel, a large bulker and a large tanker. The tables have been built using data collected through public sources, industry interviews and responses to a detailed questionnaire. However, for all of the reasons cited above, they should be considered indicative of the general magnitude of current and projected compliance costs. In all three cases, the ships are assumed to fully comply with current environmental regulations and have on board well-maintained and functioning environmental equipment, including an incinerator. All oily bilges are assumed to be processed through the OWS to the extent of the OWS’s treatment capacity. The costs for waste disposal reflect average costs that can be encountered in world-wide trading. Finally, all three vessels are assumed to comply with MARPOL at all times, regardless of the existence or not of adequate port state reception facilities.

Environmental compliance costs (USD)			
	66 000 DWT Containership (4800 TEU)	150 000 DWT Bulk Carrier	280 000 DWT Oil Tanker
Daily Ship Costs (see Appendix A)			
Daily Operating Cost	7 212	6 432	8 747
Total Daily Fixed Cost	23 431	17 326	29 102
MARPOL Capital Costs (new/replacement cost, assumed equipment life span of 15 yrs.)			
Oily-Water Separator	10000	10000	10000
15 ppm. Monitor	1000	1000	1000
Incinerator	45000	45000	45000
Annex VI equipment (proposed)	*50000*	*50000*	*50000*
sub-total	56000	56000	56000
Capital Costs per year	**4 655**	**4 655**	**4 655**
Capital Costs per day	13	13	13
Capital Costs per day (w/ Annex VI equipment)	24	24	24
Other MARPOL Fixed Costs (per year)			
Filters	2000	2000	2500
Maintenance OWS	1000	1300	1600
Maintenance OWS system pipes, valves and tanks	1530	1000	780
Maintenance Incinerator	1000	1000	1000
Maintenance Annex VI	*1500*	*1500*	*1500*
Record-keeping	14700	14700	18000
Training	2850	2850	3600
MARPOL fixed costs per year	**23080**	**22850**	**27480**
MARPOL fixed costs per day	63	63	75
MARPOL fixed costs per day (w/ Annex VI)	67	67	79
Waste and Ballast Management costs/year			
Delay caused by Oily Waste discharge	n/a*	n/a*	5000*
Garbage discharge (~70/m3 – part incinerated)	3 322	767	1 278
Oily Bilge Water (~50 USD/m3, partly processed through OWS)	0	13 140	33 641
Sludge/Slops (~50 USD/m3, partly processed through incinerator)	54 933	13 980	131 179
Total Waste Costs/year	**58 254**	**27 886**	**166 097**
Total Waste Costs/day	160	76	455
Ballast/day, @.20 USD m3, 40-day voyage	99	308	172
Total Waste and Ballast Costs/day	259	384	627
* Industry sources have indicated that delays caused by off-loading oily waste are generally insignificant – however, when they do occur because of insufficient facilities or queuing for access to facilities, they can grow quickly.			
Certification Costs			
Annex I certification per year	335	335	1370
Annex IV certification per year	87	87	87
Certification Costs per day	1	1	4

Anti-fouling Convention: TBT-free painting			
TBT painting	218 489	173 952	334 048
TBT-free paint sur-cost	63 158	38 172	95 388
Hull washing (1 every 2.5 years)	7 000	10 000	10 000
Anti-fouling Convention Compliance Costs/day	38	26	58
Total Estimated Compliance Costs per Day	**248**	**164**	**558**
Total Estimated Compliance Costs per Day w/ Annex VI	252	168	563
Total Estimated Compliance Costs per Day w/ Annex VI and Antifouling Convention	291	195	620
Total Estimated Compliance Costs per Day w/ Annex VI, Antifouling Convention and Ballast Water Management (open sea exchange)	390	502	793
*As a percentage of Daily **Operating** Costs*	*3.4%*	*2.6%*	*6.4%*
As a percentage of Daily Operating Costs w/ Annex VI	*3.9%*	*2.6%*	*6.4%*
As a percentage of Daily Operating Costs w/ Annex VI and Antifouling Convention	*4.5%*	*3.0%*	*7.1%*
As a percentage of Daily Operating Costs w/ Annex VI, Antifouling Convention and Ballast Management (open water exchange)	*6.1%*	*7.8%*	*9.1%*
*As a percentage of Daily **Fixed** Costs*	*1.1%*	*0.9%*	*1.9%*
As a percentage of Daily Operating Costs w/ Annex VI	*1.1%*	*1.0%*	*1.9%*
As a percentage of Daily Operating Costs w/ Annex VI and Antifouling Convention	*1.2%*	*1.1%*	*2.1%*
As a percentage of Daily Operating Costs w/ Annex VI, Antifouling Convention and Ballast Management (open water exchange)	*1.7%*	*2.9%*	*2.7%*

One of the most striking results of this cost simulation is that the overall environmental compliance costs are not that great and do not account for an extravagant expense in a remunerative charter market *(e.g.* time charters negotiated above operating and capital costs). Environmental compliance costs represent approximately 1-2% of the total fixed costs (capital and operating costs) of the respective vessels chosen in this simulation. However, these costs do account for approximately 3.5 to 6.5% of the daily operating costs (excluding the costs of financing the vessel). This figure is significant for several reasons.

The first is that these costs are related to systems that have no impact on the ship's ability to navigate. They represent "risk-free" cost-cutting opportunities if one only considers the safety of crew and the navigability of the vessel. A ship with a poorly-maintained and inoperative OWS can still sail and earn income, one with cracked bulkheads and an inoperative radar, however, is at great risk of a catastrophic loss of ship and cargo. Thus, substandard operators might wish to cut costs in their environmental-related expenditures first (along with, dismayingly, safety expenditures for crew).

Environmental Compliance Costs: Older Vessels in Tight Markets

Shipowners seek to ensure a positive rate of return when leasing and/or operating their vessels. However, when faced with unfavourable market conditions, many shipowners must make a difficult decision -- laying up the vessel until market conditions improve, or continuing to trade at rates that are substantially below fixed costs. Many owners choose the latter option as this at least provides them with some revenue until the market swings back into their favour at which time they expect to compensate for their losses. It is in this case -- ships trading below fixed costs in a tight charter market -- that the costs related to environmental compliance are greatest and the temptation to contravene MARPOL and related laws is strongest. This is especially true for older ships whose environmental compliance costs are greater than newer and better-maintained vessels.

For example, let us assume that in a particularly tight market, owners are negotiating vessel charters at 30% below operating costs. Let us further assume that these vessels are older and are maintained to a lower standard. The ships consume more fuel, produce more fuel sludges and oily bilges, and would -- for strict compliance with MARPOL -- require more frequent maintenance of their pollution control equipment. Let us further assume that the OWS has become inoperative because of poor maintenance and all oily bilges and sludges must be disposed of in port. The table below illustrates costs that one could expect to encounter:

Compliance Costs (USD): Older, poorly maintained ships in tight charter markets	66 000 DWT Containership (4800 TEU)	150 000 DWT Bulk Carrier	280 000 DWT Oil Tanker
Estimated Required Env. Reg. Compliance Costs per Day	391	311	750
Estimated Actual Env. Costs per day - Non-Complying Vessel	*28*	*28*	*31*
Costs of Full Compliance in a Tight Charter Market: ratio of costs to charter rate negotiated at 30% below operating costs			
Compliance Costs MARPOL	10.1%	8.6%	15.1%
Compliance Costs w/ Annex VI	10.9%	8.7%	15.2%
Compliance Costs w/ Annex VI and Antifouling Convention	12.0%	9.4%	16.4%
Compliance Costs w/ Annex VI, Antifouling Convention and Ballast Water Management (open sea exchange)	14.7%	17.9%	19.9%

Thus, in this case, environmental compliance costs range from 10% to 15% of the charter rate. With implementation of new environmental regulations, these costs could increase to 15% to almost 20% of the charter rate. A non-complying shipowner/operator could forego most of these costs by not maintaining the OWS and other pollution control equipment and dumping most, if not all, of the sludges, oily bilges and other waste overboard. With unavoidable costs ranging from 28 to 31 USD per day, the non-complying operator can expect to derive a significant unfair and illegal competitive advantage over a complying shipowner trading with similar vessels.

The second reason that these costs are significant is that while these costs are small in a remunerative or break-even market (*e.g.* timecharter rates equal to capital costs plus operating costs), they loom ever larger in a market characterised by oversupply and low time-charter and spot rates. For example, while the 1999 break-even-rates for the above ships were USD 17 326 for the Bulker and USD 29 102 for the Oil Tanker, average timecharter rates for the same type of vessels in 1999 were USD 11 260 and USD 25 750, respectively. While shipping markets are cyclical, and operators have other means at their disposal to reduce costs (e.g. through lower-cost crewing), these gaps between revenue and costs serve to underscore the pressure operators face to cut costs wherever possible (see box).

Another point highlighted by the cost calculation above is the magnitude of costs that will be faced by operators as Annex VI, the Antifouling Convention and the soon-to-be-defined Ballast Water Convention come on-line. These will represent a higher order of magnitude of costs for operators and, therefore, a greater opportunity for non-complying operators to gain an unfair competitive advantage.

The table below estimates the cost savings realised through "typical" non-compliance. Information gleaned from Port State Inspections and court cases indicate that many non-complying operators have inoperative OWS systems. For this example, let us assume that these operators do not maintain their OWS system, do not store spares and/or otherwise fix inoperative OWS systems. Let us further assume that they do not have an incinerator on board and that they dump most, if not all, of their garbage overboard. Their only MARPOL-related costs are related to (fraudulent) record-keeping in their Oil and Garbage Record Books and certification. Under these realistic assumptions, the cost savings resulting from non-compliance can be estimated as follows:

Total estimated daily environmental costs (USD): non-complying ship	66 000 DWT containership (4800 TEU)	150 000 DWT bulk carrier	280 000 DWT oil tanker
Total Estimated Daily Environmental Costs	**28**	**28**	**31**
% savings over complying operator's environmental costs	*89%*	*83%*	*94%*
Avoided Waste Disposal Costs: Sea dumping by Non-complying Ship	*209*	*139*	*1 044*

Thus the substandard operators in this case can expect to reduce their environmental compliance costs by 83-94%. Furthermore, by dumping all wastes overboard rather than retaining them on board if and when their OWS and/or incinerators fails, they can expect to reap additional savings over a compliant operator facing an OWS/incinerator breakdown. These avoided costs represent perhaps the largest category of cost savings obtained through environmental non-compliance. In absolute terms, low maintenance and repair of equipment may represent approximately USD 35 to USD 45 per day cost savings for the unscrupulous operator, direct overboard dumping (in the event of an OWS breakdown) will save the same operator anywhere from USD 140 to USD 1 044 per day.

The above examples illustrate "typical" cases on "average" non-compliant ships. As mentioned in the opening of this section, the costs associated with non-compliance can vary enormously. It would take little – say an increase in the production of bilgewater and/or HFO sludges, or a trading pattern linking a high-cost waste discharge area (*e.g.* east coast of North America) to an area where no port waste discharge facilities exist (*e.g.* West Africa) to significantly increase costs and render non-compliance more attractive.

The above calculations also assume that there are little if no delays related to MARPOL compliance. However, industry sources indicate that while delays attributable to MARPOL compliance (*e.g.* off-loading oily waste into a port reception facility) are not extremely common, when they do occur, they increase costs. These costs can be attributed to the amount of time a vessel is taken off-hire for repairs (say, in the case of having to receive and install a new OWS) or the amount of lost trading time due to delays in off-loading oily wastes due to queuing for insufficient port reception capacity. Assuming that daily revenue for a vessel is equal to its operating costs and that a vessel encounters 10 half-day delays in the year, the costs of full compliance with all MARPOL annexes and draft ballast water rules increases by approximately 1% from 6-9% to 7-10% of operating costs depending on ship type and size.

The above examples serve to illustrate that on average, while not overwhelming, certain costs *can* be saved through non-compliance with international environmental regulations. Cost savings from non-compliance must also be put into their temporal context. The longer the period of non-compliance, the larger the savings. For example, one low-risk strategy for non-compliance might involve delaying necessary repairs on MARPOL equipment in areas with ineffective Port State Control agencies. The savings from these delayed operations, and the savings from at-sea disposal of oily wastes, give the non-complying ship owner/operator an advantage over other operators who choose to maintain their equipment to a higher standard and/or seek to dispose of their oily wastes in concordance with Annex I's restrictions if their OWS is inoperative.

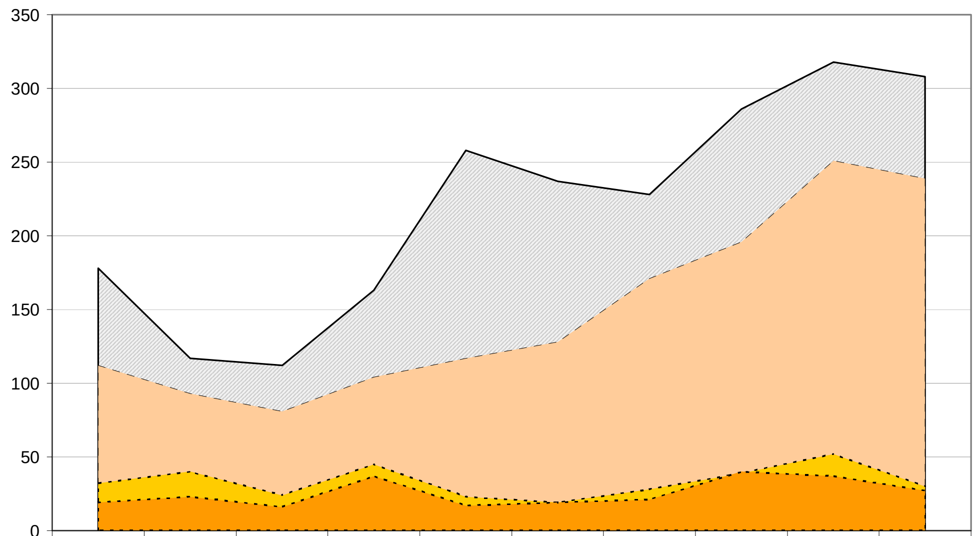
Negative incentives: MARPOL prosecutions and fines

Some shipowners, operators and crews feel that the cost savings available to them through non-compliance with MARPOL are worthwhile given the relatively small chance of being caught and/or convicted of polluting at sea. As seen previously, Port State inspections can be instrumental in discovering evidence of improper conduct. They can uncover evidence of illegal activities such as traces of oil in flexible piping found in the pump room, oil residue in the overboard discharge manifold, discrepancies in the Oil Record book, etc, but they very rarely catch vessels in the act of polluting.

Illegal discharge of wastes at sea often takes place away from shorelines and under cover of night. These two factors make it difficult for port and coastal states to detect acts of pollution, and/or positively identify the polluting vessel. Furthermore, if the discharge takes place outside of the coastal state's exclusive economic area, the sole competent authority is the flag state – some of whom have dismal records relating to the prosecution of MARPOL contraventions. In those instances, coastal states can relate details of the suspected discharge to port states who then can seek to investigate the vessel in port and, possibly, charge the master, owner and/or operator with presenting a fraudulent Oil Record book.

Many coastal states have in place some form of aerial surveillance programme consisting of aircraft outfitted with optical and/or radar detection units. These can catch photographic and or video proof of the polluting vessel's identity and, in the case of radar units, can detect polluting ships at night. These, along with the expert testimony of a qualified observer, are usually sufficient to prosecute cases where the illegal discharge takes place within the coastal state's exclusive economic zone. However the ratio of observed spills to prosecutions remains low.

Results of Maritime Pollution Surveillance Efforts in France 1990-1999



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Oil slicks reported to the authorities	178	117	112	163	258	237	228	286	318	308
Oil slicks reported in ship's wakes	112	93	81	104	117	128	171	196	251	239
Polluting vessels positively identified	32	40	24	45	23	19	28	39	52	30
Legal proceedings instigated	19	23	16	37	17	19	21	40	37	27

The results of France's surveillance efforts are representative of other efforts to apprehend maritime polluters using airborne surveillance techniques. As can be seen from the above figure, the ratio of proceedings instigated to slicks reported is typically low at an average of nearly 13% for the nine years covered. The ratio of proceedings instigated to observed ship wake pollution incidents, while still low, increases to nearly 20% and when a ship has been positively identified, nearly four out of five cases (and in some years 100% of cases) result in the instigation of legal proceedings.

Similar figures are reported by the German Federal Maritime and Hydrographic Agency (BSH) – the German Authority responsible for imposing fines in the cases of MARPOL-related convictions. In 2000, the BSH recorded 329 cases of oil pollution caused by the disposal of oily-water, fuel sludges and oily tank washings. Of these, the BSH reported that in 57 incidents, the ship was positively identified. The BSH also reported 221 cases of improperly kept Oil Record books, 51 cases of illegal OWS bypass piping and 35 cases of improperly kept Garbage record books. In 52 cases, proceedings were suspended and 38 cases were referred to the competent Flag State.

Fines for breaches of MARPOL vary enormously throughout the world. Liability for MARPOL breaches also varies among different jurisdictions with some countries targeting the master and/or crew and others seeking to place responsibility higher up the chain of command. Finally, there can exist a wide variance between the theoretical level of fines outlined in official texts and fines imposed in real-world cases which serve as the actual deterrent against illegal activity. However, the general trend – at least in OECD countries – has been for fines to increase in recent years.

Examples of recent fines and penalties imposed in the prosecution of MARPOL offences[4]			
Spain	2002	Queen T	594 000 USD
United States	2002	M/T Alkyon , Ionia Management, S.A.	1 035 000 USD
United States	2002	Fleet-wide breaches of MARPOL, Carnival Corporation	18 000 000 USD
United States	2002	Shipping Fleet, Boyang Maritime Kyeong Shin Deep Sea Fisheries Company of Pusan, Korea, Boyang Limited, Trans-Ports International (TPI) and Oswego Limited	5 000 000 USD
Canada	2002	M/V Baltic Conference	78 335 USD
France	2002	Stonegate	75 000 USD
France	2002	Nada III	75 000 USD
United States	2001	Lihue, Matson Navigation Company	3 000 000 USD
United States	2001	SS Norway, Norwegian Cruise Line Ltd.	1 500 000 USD
France	2001	Kestutis	90 000 USD
Canada	2000	Nordholt	27 265 USD
United Kingdom	2000	Stena Alexita, Partrederiet Stena Ugland Shuttle Tankers	11 737 USD
United Kingdom	2000	Crystal Rubino, Finbeta Spa	32 863 USD
France	2000	Hyundai Continental	120 000 USD
France	2000	Great Century	100 000 USD
France	2000	Irongate	45 602 USD
United States	1999	Fleet-wide breaches of MARPOL, Royal Caribbean Cruises Ltd.	18 000 000 USD
Canada	1999	Bradenburg	16 500 USD
Netherlands	1999	M/V World Prophet	81 000 USD
United Kingdom	1999	Sirte Star, Seatide Shipping Ltd	40 987 USD
United Kingdom	1999	Luckyman, Lindos Shipping Co Ltd	13 239 USD
France	1999	Far East Victory	91 470 USD
United States	1998	Fleet-wide breaches of MARPOL, Royal Caribbean Cruises Ltd.	9 000 000 USD
United States	1998	SS Rotterdam, Holland America Line Ltd.	2 000 000 USD
United Kingdom	1998	M/V Weser	411 000 USD
United States	1997	M/V Frances Hammer	509 000 USD

As seen in the preceding table, fines related to the successful prosecution of acts of intentional pollution vary enormously and can run into the millions of dollars. Owners and operators of ships facing relatively small fines may consider these to be part of the "normal" costs of doing business. For instance, a 30 000 USD fine represents approximately 82 USD per day for a vessel caught once during the course of the year. When one considers that environmental compliance costs presented in the examples on page 44 range from 164 to 558 USD per day, this seems like a relatively good bargain for the unscrupulous operator. Large fines, on the other hand, may make some shipowners and operators think twice about polluting[5]. This is especially true as fines resulting from breaches of MARPOL are typically not covered in the ship's Profit and Indemnity (P&I) insurance cover.

4 . The fines presented in this table are illustrative of the wide range of penalties imposed among OECD members. In many non-OECD jurisdictions, both the fines and the odds of being apprehended may be lower (*e.g.* in the Philippines, fines for discharging oily water and/or sludges range from USD 76 to USD 190 USD).

5. However, put into perspective, the largest penalties ever levied for breaches of MARPOL -- 18 million USD for both Royal Caribbean and Carnival Cruise Lines -- only represented 0.7% and 0.4% of operating revenues respectively for those companies in the year the fines were imposed.

Insurers belonging to the International Group of P&I Clubs cover approximately 90% of the world's merchant fleet. The remaining 10% are covered by smaller independent P&I clubs or have insurance cover through other commercial establishments. The coverage offered by all of the International Group member policies is of the "named risks" type – that is, the policies specifically state which risks are covered and which are not. All International Group members state in their rules that coverage for fines resulting from oil pollution are covered only in the case of *accidental* discharges – and seven of these specifically state that they do not cover fines resulting from breaches of MARPOL and/or other wilful misconduct (see table below).

P&I Club	Coverage of fines linked w/ "accidental discharge" of oil.	Specific clause relating to non-coverage of deliberate MARPOL violation
West of England Ship Owners Mutual Insurance Association	yes	no
The United Kingdom Mutual Steam Ship Assurance Association (Bermuda) Ltd.	yes	yes
The Swedish Club	rules not posted	rules not posted
The Steamship Mutual Underwriting Association (Bermuda) Limited	yes	no
The Steamship Mutual Underwriting Association (Europe) Ltd.	yes	no
The Steamship Mutual Underwriting Association Ltd.	yes	no
The Standard Steamship Owners Protection and Indemnity Association (Bermuda) Ltd.	yes	yes (qualified as "wilful misconduct"
The Standard Steamship Owners Protection and Indemnity Association (London) Ltd.	yes	yes (qualified as "wilful misconduct"
The Standard Steamship Owners' Protection and Indemnity Association Ltd.	yes	yes (qualified as "wilful misconduct"
The Shipowners' Mutual Protection and Indemnity Association (Luxembourg)	yes	yes
The North of England Protecting and Indemnity Association Ltd.	no	ambiguous
The Japan Ship Owners' Mutual Protection and Indemnity Association	rules not posted	rules not posted
The London Steam-Ship Owners' Mutual Insurance Association Ltd.	rules not posted	rules not posted
The Britannia Steam Ship Insurance Association Ltd.	yes	yes
The American Steamship Owners Protection and Indemnity Mutual Association Inc.	yes	yes (qualified as "wilful misconduct"
Assuranceforeningen Gard (Gjensidig)	yes	no
Assuranceforeningen Skuld (Gjensidig)	yes	no

Of course fines are not the only costs that can arise from a MARPOL prosecution – these can also include the costs of legal proceedings and lost trading time. Again, the International Group of P&I clubs only covers these costs in relation to a *successful* claim to a Club member – insofar as wilful contravention of MARPOL and its annexes does not constitute grounds for such a claim, these extra costs are therefore not covered. However, as seen in the previous section, not all prosecutions are successful and in these instances, legal and other related costs would be recoverable from the P&I.

Conclusions

MARPOL 73/78 and other international conventions clearly set out the regulatory framework for international maritime transport vis-à-vis this sector's environmental impact. These rules apply to all ships sailing the flag of countries that have ratified these Conventions and their annexes. Abiding by these rules, however, requires ship owners and operators to adopt specific operating procedures, invest in equipment and build and/or modify ships and engines according to specific technical requirements. As such, these rules bear certain compliance costs.

The most important compliance costs are those related to structural changes in ships and, eventually, engines and ballast water treatment. In particular, requirements for mandatory double hull construction and the installation of SBT systems have been quite large compared to many other environmental compliance costs. However, it is perfectly legal for a 25+ year-old tanker to operate a CBT/HBL system and compete in the same trades as a more recent tanker. While the costs of operating such a ship can be lower due to the lower capital costs, this is not a case of "unfair" competition from a non-complying vessel.

Generally the structural changes brought about by MARPOL, by their nature, are not sources of "unfair" competition by operators. This cannot be said for the operational requirements of MARPOL and other environmental maritime conventions. What happens on board a ship, as opposed to the shipyard, can and is a source of "unfair" non-compliance by unscrupulous operators.

Take the example given above, two ships, one pre-MARPOL CBT tanker operating with HBL and one post-MARPOL double hull SBT ship compete for the same spot charter. The first will have higher operating costs (if maintained to standard by the owner) and lower financing costs. The second might have lower operating costs but will have much higher financing costs. All things being equal, a charterer interested primarily in the lowest price might go with the former. Even though cheaper and older, the former has not contravened MARPOL and its lower cost does not constitute an ill-gained competitive advantage.

Now, take the case of the same vessel as in the first instance and put it up against the same type of ship for another spot charter. However, in this case, the second boat decides to forgo the operational requirements calling for it to use HBL. In this case, the second ship will derive an "unfair" competitive advantage equal to the extra amount of oil it can load in contravention to the HBL restriction (5-8% more cargo can be loaded in this case thus increasing the attractiveness of this boat to the cost-focused charterer).

Put in the perspective of average operating costs, MARPOL's operational requirements are not typically a great source of cost outlays. The cost of maintaining and repairing equipment in order to meet discharge requirements are not terribly large – in a remunerative market. This paper estimates these to be in the order of 3% to 6% of daily operating costs on a MARPOL-compliant ship. However, when pushed to the wall by low charter rates and unchanging and/or increasing operating costs – some shipowners might seek to gain whatever savings they can by lowering their maintenance standards, repair frequency, seafarer training, etc. This paper estimates that environmental compliance costs on older vessels operating in an unremunerative market (for instance, with charters negotiated at 30% below operating costs) quickly swell to 9% to 15% of daily operating costs. Some shipowners and operators may even feel that contravening MARPOL may be a "safe" cost-cutting strategy in that they can reduce their environmental compliance costs without endangering the integrity of the vessel, its crew or its cargo. This is a choice fraught with financial risk because when environmental subsystems fail on a vessel – especially those systems responsible for the management of wastes and water – compliance costs suddenly increase in proportion to the wastes to be unloaded in ports, the time necessary to unload these wastes and the cost of repairs to be undertaken.

There are several possible strategies to address shipowners' and operators' non-compliance with operational requirements of international environmental rules.

The first is preventative. The existence of better enforcement, inspection, surveillance and more deterring penalties factor into the decision to infringe MARPOL's requirements. Technology advances allowing Coastal States to detect bilge dumping at night, better oil sample identification methodologies and stiff deterring fines (recently as high as USD 18 million each in two high-profile cases against cruise lines systematically bypassing their ships' OWS) all serve to deter shipowners from risking non-compliance with MARPOL. However, most fines levied in cases of maritime pollution are as high and therefore may not serve as an adequate deterrent – especially insofar as their payment represents a smaller outlay than environmental compliance. Furthermore, efficient surveillance, effective port state controls, well-functioning courts and heavy fines are all reunited in only a few of the globe's regions. The absence of one, or several of these factors, increases the facility with which substandard operators can breach international environmental regulations.

The second is to provide shipowners and operators with the opportunity to comply. As seen previously, the necessity for Port States to supply adequate port waste reception facilities is a necessary pre-condition for ensuring compliance with many of MARPOL's annexes. However, these are notoriously lacking in many parts of the world. Furthermore where they do exist, they are often impractical or expensive. Port States have a responsibility to ensure that ship's wastes can be received onshore in good conditions. Furthermore, they have an incentive to develop fee structures and waste disposal requirements that make it easier, rather than harder, for ships to comply. In this respect, integrating at least a portion of the waste disposal fee in to harbour duties and requiring the discharge of certain types of wastes (as recently adopted within the EU) would seem to be a good first step.

A third strategy would be to continue to regulate the on-board operations of ships. This has formed part of the IMO's approach in the past and much progress has been made with respect to putting in place verifiable systems to track environmental compliance onboard ships (*e.g.* different record books, monitors and recording devices). However, in their current configuration, these requirements sometimes fail not because they are ill suited to the task but because they require strong and constant oversight by Port States and Flag States. Better enforcement of what exists would be more helpful than the imposition of new rules.

A fourth strategy exists as well, and goes to the heart of the problem of illegal oil discharges from ships. The principal source of petroleum hydrocarbons dumped at sea by ships are by far the remnant fuel oil sludges that non-complying vessels do not wish to keep on board and discharge into ports as required by MARPOL. That ships produce these sludges is no surprise as the vast majority of ocean-going vessels consume one of the "dirtiest" of all fuel sources available - heavy fuel oil. While progress has been made in cleaning up this fuel, it still remains the final residue of the oil refining chain and, as such, will remain a source of toxic and persistent sludges. Weaning the maritime sector away from these fuels and towards cleaner sources of energy, much as what has been done for land transport, would go a long way towards reducing sludge production, oil discharges and the competitive advantage accruing to non-compliant vessels.

Finally, this paper has tried to highlight the financial advantages that can accrue through non-compliance. While a small percentage of shipowners and operators would contravene international environmental rules no matter what the economic context – almost by habit and/or a lack of "environmental culture" (much as some operators simply have not developed a "safety culture"), many choose to avoid compliance costs when margins are tight. The maritime sector is characterised by a high level of fragmentation and a near chronic oversupply problem. Ensuring a more balanced shipping market may go a long way towards reducing the pressure on shipowners and operators to achieve savings no matter what the cost. In this respect, addressing some the fundamental supply/demand imbalance and possible ways to relieve this imbalance may hold promise for reducing the incidence of operational pollution from ships.

APPENDIX A: SAMPLE SHIP CAPITAL AND OPERATING COST BUDGETS (1999 DATA) AND SHIP CHARACTERISTICS

(see table on page 43)

	66 000 DWT containership (4800 TEU)	150 000 DWT bulk carrier	280 000 DWT oil tanker
Year built	1992	1992	1992
Size (DWT)	66 000	150 000	265 000
Ship Budget			
Replacement Cost	71 218 866	47 835 843	89 378 355
Annual Capital Cost	5 919 893	3 976 237	7 429 356
Daily Capital Cost	**16 219**	**10 894**	**20 354**
Crew Cost (ITF Crew)	997 875	828 206	1 094 467
Lubes & Stores	355 875	314 381	488 764
Maintenance & Repair	686 750	378 495	448 845
Insurance	472 375	630 391	904 461
Administration	119 625	196 194	256 169
Fixed Annual Operating Cost	2 632 500	2 347 667	3 192 706
Fixed Daily Operating Cost	**7 212**	**6 432**	**8 747**
Total Annual Fixed Cost	8 552 393	6 323 904	10 622 062
Total Daily Fixed Cost (break-even point for Timecharter rate)	**23 431**	**17 326**	**29 102**
Ship Waste/Ballast Production			
HFO consumption (tonne/day)	170	60	80
HFO Sludge Production (m3/day)	2.86	1.01	1.34
Bilge Water Production (m3/day)	1.10	1.70	3.00
Tank Washing (6000 m3: washing 3-4 holds/year) m3/day			16.44
Total Slops/sludge Produced/day	3.01	1.25	7.52
Ballast (m3 per voyage - ballast voyage for tanker)	19 800	61 500	68 900
Other Garbage (m3/day)	0.16	0.05	0.07

Source: US ACE 2000 (Economic Guidance Memo), EMARC Project, Drewrys.