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FINAL REPORT

Project: **Cost Analysis of Compliance with MARPOL Annex I OWS Regulations**
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Project Description:

Even noncompliant shipowners incur some costs related to MARPOL Annex I oily waste management regulations in order to trade in global waters. However, the cost differences between an Owner investing only in "lip service" compliance, such as maintaining up to date certificates, installing an Oily Water Separator on board, and filling out a falsified Oil Record Book, versus a prudent Owner attempting to address the intention of the regulation, can be significant.

This project is an effort to quantify this cost difference and compare it to the risk of discovery and prosecution of non-compliance, which has become more common and costly in recent years, particularly in US waters.

The primary deliverable of this project is a spreadsheet analysis of shipowner costs related to MARPOL Annex I compliance[1]. This spreadsheet is available for download here, and can be edited by shipowners and other stakeholders to more accurately reflect their specific costs. The spreadsheet may help shipowners make an economic case for investments in compliance, as well as identify potential cost saving opportunities and optimal ship-specific approaches to oily waste stream management. The majority of this report describes the approach, intended use and limitations of the spreadsheet.

Based on the cost data gathered during our project, it was observed is that if a shipowner takes a ship-specific approach to developing an oily waste management plan for a particular vessel, they could generally be economically competitive with non-compliant vessels when the risk of enforcement actions was taken into account. However, for some vessels[2] it may still be (economically) advantageous to pollute, which implies that the USCG, DOJ and other international enforcement agencies may need to further increase efforts at discovery and prosecution, or increase penalties, to disincentivize oily waste pollution for all shipowners.

[1] This spreadsheet does not take into account costs to the environment, public health, and crew burden.
[2] Depending primarily on the vessel's area of operation and volumes of oily waste generation.

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INTRODUCTION

In recent years, compliance with MARPOL Annex I, the International Maritime Organization regulation covering the management of shipboard oily wastes (bilge water and sludge) has made significant strides. However, full compliance with the regulation is still elusive, and a number of large and small shipowners each year are discovered actively subverting the regulation, and discharging oily wastes directly overboard. The economic motivations of non-compliance are questionable, and this report attempts to dispel the misconception that polluting will always save a shipowner money over the long term.

This report does not fully describe oily waste management approaches and current practices, and assumes their readers are relatively fluent in this matter. For more background on oily waste management as regulated under MARPOL Annex I and USCG APPS regulations, please see the extensive references collated here as part of the MAX1 Studies on Oily Water Separator technology conducted in 2015.

The purpose of this document is to detail the approach taken with a spreadsheet cost analysis of oily waste management, the spreadsheet's intended use and limitations, and our overarching findings such as cost saving opportunities and current bottlenecks for achieving full compliance. The report also gathers a large amount of economic data in one location, which we hope will be useful for various stakeholders, particularly shipowners and government officials.

The data has been organized with shipowners in mind. Therefore, it does not include environmental and psychological costs and benefits of MARPOL Annex I, since these are not incurred by the shipowner, but rather by the general public and shipboard crews. A cost benefit analysis of shipboard environmental regulations including these stakeholders would be an interesting addition to the work conducted in this study.

We have also chosen to exclude a number of potential benefits of compliance that lack sufficient data or are difficult to quantify, such as:

- *Reputational financial impacts (e.g. compliant Owners may receive higher value contracts, whereas polluting Owners may lose contracts with government or big oil in the case of discovered non-compliance)*
- *The fleet effect, where a vessel is discovered out of compliance, leading to higher scrutiny of the Owner's other vessels, and quick escalation of costs if non-compliance is a fleetwide problem*[3]
- *The potential economic effect of increased Port State Control inspections if the vessel is considered high risk for non-compliance (e.g. the US PSC Qualship21 initiative)*

Even excluding the above considerations, it was found that the risk of discovery and prosecution of MARPOL Annex I violations in US ports of call is a significant cost consideration and one that violating shipowners should increasingly consider. We hope that the spreadsheet analysis provided allows shipowners to incorporate these considerations into their decision-making process more easily.

[3] Even if other vessels are not proven to be out of compliance, discovery of non-compliance on a single vessel in a fleet may lead to a sentence including implementation of Environmental Compliance Plans on a number of vessels. The fleet effect essentially means that a large shipowner should be more careful to comply than the spreadsheet would indicate, since it only reflects the potential costs of non-compliance for a single vessel.

EXISTING LITERATURE & DATA SOURCES

2003 OECD Study

In 2003, the Maritime Transport Committee of the Organisation of Economic Cooperation and Development published a paper titled "Cost Savings Stemming from Non-Compliance with International Environmental Regulations in the Maritime Sector", which focused on MARPOL Annex I costs.

The OECD paper detailed costs of compliance for three example vessels: a 66,000 DWT containership, a 150,000 DWT bulk carrier, and a 280,000 DWT oil tanker.

Ultimately, the OECD paper concluded that the costs of compliance with MARPOL Annex I (including equipment, maintenance, training, and disposal costs) resulted in significant cost savings for polluting shipowners, especially in non-remunerative markets. In other words, the paper concludes that it pays to pollute. The paper calculated the following costs for its example vessels:

	Containership	Bulk Carrier	Oil Tanker
Annex I capital costs per year (15-year equipment life span)	$4,655	$4,655	$4,655
Annex I fixed costs per year (maintenance, training, etc.)	$23,080	$22,850	$27,480
Annex I waste disposal costs per year	$58,254	$27,886	$166,097
Annex I certification costs per year	$335	$335	$1,370
Total MARPOL Annex I costs per year	**$86,324**	**$55,726**	**$199,602**

Figure 1. MARPOL Annex I compliance costs according to 2003 OECD study

The paper also estimates all environmental regulatory costs[4] as a percentage of operating and fixed costs, as follows:

	Containership	Bulk Carrier	Oil Tanker
All env. regulatory costs as a % of total daily operating costs	6.1%	7.8%	9.1%
All env. regulatory costs as a % of total daily fixed costs	1.7%	2.9%	2.7%

Figure 2. Environmental compliance costs as a percentage of total ship costs according to 2003 OECD study

The OECD paper discusses the potential offsetting effect of fines for polluters, but draws the conclusion that these fines and the likelihood of being caught were too low, and therefore does not appear to have taken these risks into account in the financial analysis.

While it is unclear whether the effect of fines in 2003 would have offset the costs of compliance then, both the size of fines and likelihood of being caught and successfully prosecuted with MARPOL Annex I violations (particularly in the United States) have increased in recent years, and this risk should be included in a cost analysis of non-compliance today.

The paper also does not address the fact that a non-compliant shipowner would still incur some costs related to MARPOL Annex I in order to trade in global waters. For example, a shipowner would not be able to obtain a shipbuilding contract (for a vessel over 400 gross tons) that doesn't include installation of an Oily Water Separator, Oil Content Meter, bilge water and sludge holding tankage,

[4] Environmental regulatory costs in the OECD paper consist of MARPOL Annex I, MARPOL Annex VI, Antifouling Convention and Ballast Management (open water exchange) costs.

and other mandatory equipment under MARPOL Annex I, although they may choose the cheapest, bare minimum equipment. This type of "lip service" compliance should be the baseline in an assessment of the true costs of compliance (instead of a zero-cost baseline).

This project attempts to address these issues with the 2003 OECD paper, in order to more accurately reflect the cost analysis of complying with MARPOL Annex I regulations in the present regulatory environment.

MAX1 Studies

In 2015, Martin & Ottaway conducted a study of shipboard oily waste management called the MAX1 Studies. The study focused on consolidating existing research and best practices in oily waste management, and used widespread stakeholder collaboration to identify how to continue to improve MARPOL Annex I compliance.

Part of the MAX1 Studies involved a survey circulated to maritime professionals, including a large number of shipboard engineers. The survey was electronic, anonymous, and conducted from April-July 2015. The survey ultimately yielded over 500 responses.

The results of this survey are relied on for a number of assumptions made in this cost analysis. Most importantly, the survey was used to develop an estimate of the proportion of vessels not complying with MARPOL Annex I today.

Other Literature

Academic, industry, and government literature on shipboard oily waste management has historically been fragmented and not well circulated among stakeholders. However, a large part of the 2015 MAX1 Studies was devoted to consolidation of this information, and resulted in the MAX1 Chronology. The resources available in the chronology were often referenced to assist with this project.

The MAX1 Chronology was also updated in order to reflect additional research found during this project, resulting in the version dated February 9, 2017.

Data Sources

Compliance cost details were provided by a number of ship owners, operators, manufacturers, suppliers, and other members of the maritime industry.

Risk of discovery of non-compliance and Port State Control actions were established based on detailed data provided by the United States Coast Guard, including environmental events, actions, and operational/restriction controls throughout the USA for 2014-2015. This was supplemented with more general data in annual reports from the US Coast Guard and the nine Memorandum of Understanding areas (Paris, Tokyo, Acuerdo Latino, Caribbean, Mediterranean, Indian, Abuja, Black Sea, & Riyadh).

The risk of subsequent action by the Department of Justice and cost data for fines and community services payments were sourced from the United States DOJ's Environmental Crimes monthly

bulletins. We aggregated MARPOL Annex I prosecution and sentencing data for the past 10 years for this purpose[5].

Related prosecution and post-sentencing costs such as legal fees, management, and heightened monitoring and scrutiny (e.g. creating and implementing an Environmental Compliance Plan), were estimated in consultation with shipowners, maritime lawyers, and other industry players.

Raw data used to perform our cost analysis, stripped of sources and vessel names where applicable, can be found in the Appendices of this report.

Review and further analysis of this data would provide more granular insights. Please feel free to forward any additional work performed on the data to info@martinottaway.com for inclusion in the MAX1 Chronology.

[5] It is possible that the DOJ does not include the outcomes of all MARPOL Annex I related cases in their bulletins, and therefore that the risks of non-compliance may actually be higher than the spreadsheet would indicate, since the risk of DOJ prosecution is determined by the data reported in these bulletins. If additional prosecution and sentencing data becomes available, the spreadsheet could be updated to reflect this. Also note that this analysis does not include fines levied outside the United States.

METHODS

Capital and Operating Costs

General Approach

The first part of the cost analysis involved quantifying the capital and operating costs associated with MARPOL Annex I.

Many of these costs vary depending on the characteristics of the ship in question. We limited the required inputs to the following main items:

- *Ship type: bulk carrier, tanker, containership, passenger vessel, or other*
- *Ship size, using deadweight tonnage*
- *Main engine rating*

Assumptions stemming from these inputs can be found in the "Assumptions" tab of the spreadsheet. For example, the cost of sludge disposal is a function of the amount of sludge generated per day, which is a function of the daily bunkers burned, which itself is a function of the main engine rating.

We estimated costs for two types of Owners: the "Prudent Owner" and "Lip Service Owner". We assume that our "Prudent Owner" incurs all costs that might have a positive impact on compliance, but still makes decisions to minimize costs without negatively impacting compliance. For example, our Prudent Owner would choose to legally incinerate their sludge outside of ECAs if it was less costly than discharging to shore or a barge. Our "Lip Service Owner" counterpart only incurs costs that are unavoidable in order to trade in global waters. For example, no newbuild vessel over 400 gross tons would be able to leave the shipyard without installing an Oily Water Separator on board; we would expect the Lip Service Owner to install the cheapest allowed OWS system, while a Prudent Owner would install a top of the line OWS system. We would also expect our Lip Service Owner to pollute directly overboard, in order to avoid incurring disposal and equipment maintenance costs.

The capital costs were converted to an annualized equivalent using a 6% yearly discount rate. A 30-year useful life was used for all vessels except passenger vessels, which were estimated at a 45-year useful life. These estimates are based loosely on the average age of scrapped vessels of various types from 1989-2015, calculated from M&O's proprietary valuation database.

The following annuity equation was used for annualizing capital costs:

$$Annuity = \frac{Kr(1+r)^n}{((1+r)^n - 1)}$$

Where *K = capital expenditure at time 0*
r = discount rate
n = number of years of annuity

Operating costs vary widely depending on shipboard practices for oily waste management. We therefore built flexibility into the spreadsheet analysis to allow for different approaches. This flexibility should also assist shipowners with identifying opportunities for reducing their costs.

For the default version of the spreadsheet, we assumed that sludge generation was a direct function of bunkers consumed (1%), as per IMO guidance (MARPOL Annex I, interpretation to Reg 12)[6]. Bilge water generation is much more difficult to estimate, since it depends on a large number of factors, including but not limited to:

- *Ship/engine size*
- *Ship type/operation*
- *Fuel type burned*
- *Drains into the bilges versus to selected tanks (e.g. conformance to IBTS Code)*
- *Mechanical versus gland seals on pumps*
- *Engine room procedures (e.g. use of drip pans, frequency of washing/cleaning)*
- *Age and condition of engine room equipment (e.g. main propulsion and auxiliary equipment leakages, piping leakages)*
- *Ship route and area of operation (e.g. condensation as a function of ambient temps, arid/tropical env.)*

For our purposes, we estimated the amount of bilge water generated using an IMO formula for determining bilge water tankage based on the vessel's main engine rating, as follows:

Main engine rating (kW)	Capacity (m^3)
Up to 1,000	4
Above 1,000 up to 20,000	P/250
Above 20,000	40+P/500

Where P = main engine rating in kW

Figure 3. IMO bilge water tankage recommendation, sourced from p. 5 of MEPC.1/Circ.642

To convert to daily bilge water generation, we relied on IMO guidance that oily waste tankage should be capable of holding 30 days of waste (MARPOL Annex I, Reg 10.15.1).

This method results in a relatively high estimate of bilge water generation, and it is noted that with different shipboard practices, bilge water can be drastically reduced.

We discuss some specific capital and operating costs in more detail below.

Oily Water Separator

The primary required equipment purchase for compliance with MARPOL Annex I is an Oily Water Separator ("OWS"). This piece of equipment separates water from the other components of bilge water, such as oil, dirt, cleaners, and other particulates, so that the separated water may be discharged overboard.

Not all ships' crews use OWS technology[7], but all ships of 400 gross tons and above are required to have an OWS of sufficient capacity installed on their vessel as per MARPOL Annex I, Chapter 3,

[6] The average is closer to 0.5% for vessels using MGO or other fuel not requiring shipboard purification, so this assumption should be adjusted if your ship burns MGO for a large proportion of your voyages.

[7] If a crew chooses not to use their OWS, under current regulations, they must discharge all generated bilge water to shore facilities or reception barges. There are a number of other feasible options from a technical perspective in order to maintain the 15-ppm requirement, such as bio-based treatments, electrocoagulation, and filters using oleophilic materials, which may ultimately be cheaper than OWS technology, but these options would be difficult to get regulatory approval for as a *substitute* for an OWS.

Regulation 14. Current OWS are compliant with either MEPC 60(33) or MEPC 107(49), but ultimately all MEPC 60(33) OWS systems will be phased out. Therefore, for the purposes of our cost benefit analysis, we have assumed that our vessels must achieve compliance with MEPC 107(49). This means that the OWS system will need the following features:

1. *MEPC 107(49) certified bilge alarm or Oil Content Meter ("OCM"), which records alarm conditions*
2. *Tamper proof OCMs*
3. *OCM alarm activation whenever clean water is used for cleaning or zeroing purposes*
4. *Separator capable of achieving 15 ppm on Type C[8] emulsion*

The Oil Content Meter ("OCM") ensures that the effluent from the OWS going overboard has less than 15 ppm hydrocarbon content. On MEPC107(49) systems, OCMs are sold together with OWSs.

There was found to be a large price range for various OWS systems on the market (see Appendix B). The most expensive systems were about 4 times more expensive than the cheapest systems. For our default spreadsheet, we assumed that our Prudent Owner would install the most expensive system[9], and the Lip Service Owner would install the least expensive system. We note that expensive does not always mean higher quality. However, more expensive equipment does generally provide more customer support.

The default spreadsheet was built with OWS pricing as a step-wise function of bilge water generation, as follows:

Daily Bilge Water Generation	Lip Service Owner	Prudent Owner
<1 cubic meter	$22,500	$90,000
1-2.5 cubic meters	$30,000	$120,000
>2.5 cubic meters	$35,000	$140,000

Figure 4. OWS pricing used for spreadsheet analysis

After consultation with OWS suppliers, we decided to assume that the installation of the OWS system would cost approximately the same amount as the equipment (e.g. if the OWS equipment cost $90,000, installation would cost approximately the same amount, bringing the total OWS cost to $180,000).

We have assumed that the OWS processes about 95% of the bilge water for discharge overboard, and that the residual 5% waste is directed to the sludge tank[10]. In reality, a lower quality OWS would have a higher residual waste percentage (maybe 5-15% residual waste), but since we are assuming the Lip Service Owner dumps sludge directly overboard and does not use their OWS, we did not need to incorporate that consideration into the model.

It depends on the model, but a higher quality OWS tends to have lower consumable and maintenance costs over the long run. The spreadsheet assumes $2.50 per cubic meter processed

[8] Type C testing fluid consists of a diesel, fuel oil, and fresh water mixture which has been emulsified using mechanical agitation, detergent, solvent and particulate matter. Oily droplets 0-10 microns will not separate out using gravity separation devices that exploit buoyancy differences between the droplets and water. Therefore, 107(49) OWS technology generally requires post gravity separation treatment in order to pass testing.
[9] A Prudent Owner could very well decide to take a different strategy, installing a cheaper OWS system and investing more in training, or deciding to land oily wastes to shore, for example.
[10] This is based on manufacturer provided data in Attachment B of 2011 EPA Report "Oily Bilgewater Separators".

for all maintenance and consumable costs, for a higher end OWS model (it might be closer to $4.00 for a lower end model). These numbers are based on industry input and the paper noted in Footnote 11. We assumed that our Lip Service Owner would not spend any money on OWS consumables and maintenance, although in reality they might spend some amount on the OWS system in order to pass Port State Control inspections.

OWS consumables may consist of replacing filters, or changing the media (generally some combination of sand and an oleophilic material) from the 1st stage coalescer. These tasks also have small associated disposal costs. All of these costs are incorporated into the above figures of $2.50/$4.00.

A separate maintenance item is the yearly OCM re-calibration, complete with an associated certificate to verify its calibration for class, flag, and PSC officials. This also depends on the unit, but ranges from $500-$2,000 per year.

We assume in the model that our Prudent Owner uses their OWS to process all their bilge water, and therefore that there are no bilge water disposal costs except for the 5% residual routed to the sludge tank. If shipboard practice is to land some or all of their bilge water to shore, then costs should be added to that line item. Bilge water disposal costs should be at least as much as sludge disposal costs, and in some cases higher.

A final capital cost consideration related to the OWS is that ships may also be fitted with a white box. The white box monitors and controls the discharge from the OWS, and is fitted with a stainless-steel cage in an effort to be tamper-proof. Ships are not required to install a white box, unless it is mandated as part of an Environmental Compliance Plan. In our default spreadsheet, our Prudent Owner has installed a white box. However, a Prudent Owner may instead decide to invest more in environmental training for their crew rather than install a white box and achieve a similar effect.

Incinerator

Ships may or may not also be fitted with an incinerator in order to treat sludge, although an incinerator is not required under Annex I. We have assumed that both of our Owners have installed incinerators, since this is general practice.

For our default spreadsheet, the Prudent Owner has installed a less expensive incinerator with an energy requirement of 250 L MGO per MT sludge. (For less expensive systems, depending on the quality of the sludge and the type of incinerator, the energy requirement could be anywhere in the region of 200-500 liters of MGO per metric ton of sludge incinerated.) However, the Prudent Owner may instead decide to install a much more expensive incinerator with a very low energy requirement. This approach can be altered in the spreadsheet by amending line items for “Incinerator cost” in the “Cost” tab and “Incinerator energy requirement” in the “Assumptions” tab.

The pricing for incinerators was assumed to be approximately equal to the cost of an OWS system purchased by the Lip Service Owner. Again, the installation cost was assumed to be equal to the equipment cost. We have assumed that the Lip Service Owner and Prudent Owner install the same system for the default version of the spreadsheet.

Before incinerator use, the water content in sludge is normally evaporated by heating the sludge with waste heat. This reduces the sludge volume by the proportion of water content, which can vary significantly. We have assumed 20% water content in sludge for the default spreadsheet.

The incinerator should be capable of incinerating practically all of the sludge, but would need to be cleaned out approximately once a year. We have assumed a yearly incinerator and tank cleaning of approximately $2,000, which may be conducted by either outside contractors, or represented as overtime pay by the crew, and includes disposal costs.

Waste Disposal

Alternatively, the ship may choose to avoid the incineration energy costs and dispose of their sludge ashore or on a reception barge. The disposal of sludge and bilge water varies widely geographically, and can also fluctuate greatly over short spans of time.

Our estimates are based on data provided by shipowners. Theoretically, prices could be found in the Port Reception Facilities Database ("PRFD") within the IMO's Global Integrated Ship Information System ("GISIS"), but spot checks of the database yielded no cost data for disposal costs.

All international ports are required to accept sludge and bilge water wastes under Regulation 38 of MARPOL Annex I, but implementation and enforcement of these regulations has been poor, and many PRFs are ad hoc, prohibitively expensive, or will outright refuse to accept oily wastes.

While rare, occasionally oily waste discharge may result in delays to the ship's schedule. With proper planning and a compliant PRF, this should not occur.

For the purposes of our cost estimates, we used prices provided by shipowners operating in North America, South America, Europe and Asia, with the following general statistics:

	Price per cubic meter
Mean	$105.00
Median	$53.00
Min	- $50.00
Max	$528.00

Figure 5. Sludge shore disposal prices for various locations

At some ports, disposal prices are "free", so they are incorporated into port costs for all vessels, regardless of whether the vessel discharges oily wastes at the port. European countries are required to at least partially incorporate waste costs into the general port fee, at a minimum of 30% of the waste disposal cost[11]. This approach is promising, since it allows crews to responsibly dispose of their wastes without any additional costs to the shipowner, narrowing the operational cost gap between compliers and non-compliers.

In other ports, such as some Chinese ports, ships are actually paid for their sludge, where the sludge is re-processed into fuel.

Our default spreadsheet assumes a sludge discharge cost of $70 per metric ton. However, when possible, this number should be altered to reflect prices in the area where the specific ship discharges its sludge, since disposal costs represent a large part of the cost analysis.

[11] Directive 2000/59/EC on Port Reception Facilities

We have built the spreadsheet to calculate both the cost of discharging sludge and the sludge incineration energy cost (both methods use the sludge volume after evaporation), and choose the lower of the two costs.

Training

Crew training for environmental compliance can be divided into two main types:

1. *Operational training*
2. *"Environmental culture" training*

Operational training should consist of OWS operation/troubleshooting, OCM troubleshooting, proper record keeping, and bilge water and sludge management best practices.

"Culture" training can take a number of different forms, but the common goal is to convince crews that environmental compliance is a priority for their shipowner[12]. Without this training, crews may believe that they are better serving their Owners by violating MARPOL Annex I. Cost-effective "culture" training is generally a top-down approach, where Owner management communicates environmental compliance as a priority to their officers, who communicate the idea to their engine room crews.

The costs of these training initiatives can vary widely, but for the purposes of the spreadsheet we have assumed an environmental training cost of $500/person/year, to include training of the Master and Chief Engineer, who would be expected to disseminate that information to their crew. This cost could be representative of a yearly seminar with Masters and C/Es from a fleet of vessels. Only the Prudent Owner incurs this cost in our analysis.

An additional capital cost of $2,000 is incorporated into the OWS commissioning manufacturer's representative line item for the Prudent Owner to cover OWS operational training.

Other Costs

The ship also requires a MARPOL Annex I certification and IOPP Supplement to trade. The initial certificate costs are normally built into the shipbuilding contract along with other certificates, and the annual endorsements are also grouped together with a large number of other certificate endorsements. It is difficult to separate out exactly how much the MARPOL Annex I certification costs, but it does not have an impact on the cost analysis, since all ships must incur this cost in order to trade in global waters. We have assumed $1,000 for the initial certification and $500 for annual endorsement.

There are also some costs associated with engineering design. For MARPOL Annex I compliance for a newbuild, these costs are relatively small. However, due to changing regulations in recent years (particularly those arising from the change from MEPC 60(33) to MEPC 107(49)), many vessels were required to make more expensive shipboard modifications. For our purposes, we assumed that the engineering costs were for a newbuild vessel rather than a retrofit.

We did incorporate a large differential between engineering costs from a Prudent Owner and Lip Service Owner. This is because we assumed that the Prudent Owner would incorporate an IBTS system or take some other approach to streamline their engine room oily waste management system,

[12] Unlike operational training, "environmental culture" training is not explicitly required under MARPOL.

which can be a significant upfront cost, but tends to save money and crew energy downstream. Streamlining E/R waste management may result in a significant reduction in bilge water generation, but we did not have good data on the amount of reduction and therefore did not incorporate this into our analysis[13]. For a shipowner to alter the analysis to incorporate this, they should directly edit the "Bilge water daily generation" line item in the Assumptions tab.

Another interesting consideration is record keeping. We have excluded record keeping costs from our analysis for two main reasons. First of all, industry input indicates that shipowners do not typically hire additional crew members to deal with increasing environmental record keeping requirements, and that additional record keeping demands tend to represent an added crew burden instead. Since we are only looking at the economic case for shipowners, the extra crew burden is outside of our scope. Secondly, the time requirement to maintain a falsified Oil Record Book[14] is similar to (if not higher than) maintaining a correct ORB. We would expect that a Lip Service Owner would need to maintain a falsified ORB, since this is an item regularly checked by PSC.

PSC and DOJ Costs

General Approach

The second part of the cost analysis was to assess the risks involved with MARPOL Annex I noncompliance – i.e. the risk of getting caught and punished. The risks were divided into two main categories: the risk of detention by Port State Control ("PSC") and the risk of prosecution by the Department of Justice ("DOJ").

This process was also two-fold, as we had to both detail the potential costs involved with PSC/DOJ actions, and make an assessment of risk for each of these actions.

We assumed that the Prudent Owner, seeking full compliance with MARPOL Annex I, would incur only one potential PSC/DOJ cost: a reported non-compliance. This means that when there was an issue with Annex I compliance (e.g. the OWS was malfunctioning), the Prudent Owner would report this issue to the USCG before arrival in port, the USCG would attend on board, and the shipowner would incur about $20,000 of costs to rectify the issue. The annual risk of a reported non-compliance for a Prudent Owner was estimated to be 10%[15].

The remainder of the PSC/DOJ costs relate only to our Lip Service Owner. Our approach results in an inherent assumption that a Prudent Owner would not be subject to a detention or prosecution for MARPOL Annex I violations. In recent years, our analysis shows that this assumption holds well.

Risk of a PSC detention was based on USCG PSC data covering 2014-15. Through analysis of this data, we found that the average number of US PSC detentions related to MARPOL Annex I violations per year was 22 detentions. We then used this number as follows:

$$Likelihood\ of\ detention\ if\ noncompliant = \frac{\#\ of\ vessel\ detentions}{\frac{\#\ of\ vessels\ visiting}{Proportion\ of\ noncompliers}}$$

[13] This would not have a significant effect on our analysis as long as the vessel is not landing bilge water to shore.
[14] The shipboard document where bilge water and sludge operations are recorded.
[15] In effect, a Prudent Owner would be investing about $2,000 a year in communicating with Port State Control agencies (an excellent investment, in our opinion).

We used a similar approach to estimate the risk of a DOJ prosecution, using aggregated DOJ monthly bulletin data from 2007-16 showing an annual average of eight Annex I vessel convictions per year, as follows:

$$Likelihood\ of\ prosecution\ if\ noncompliant = \frac{\#\ of\ prosecutions}{\frac{\#\ of\ vessels\ visiting}{Proportion\ of\ noncompliers}}$$

The proportion of noncompliers is inherently elusive. However, it is an important number for our analysis. We note that small changes to this number result in significant changes to the overall cost analysis - if the risk of getting caught goes up by a small amount, the estimated costs of a Lip Service Owner go up significantly.

The MAX1 Studies survey, which includes over 500 anonymous responses to the question:

"In your opinion, what percentage of ocean-going ships' crews violate MARPOL Annex I?"

indicates that the percentage of non-compliers is approximately 10%[16].

However, this estimate relies on the opinions of all maritime industry professionals, which may be out of date or misinformed. To refine our non-compliance estimate, we looked at the USCG PSC data, and specifically the percentage of all detentions that are related to MARPOL Annex I violations. Since whenever a vessel is detained, it will almost certainly undergo an extended shipboard inspection, we would expect detentions for other matters to yield any deficiencies in Annex I practices. Using this approach with our PSC data yielded a noncompliance estimate of 8.5%[17].

We used the above equations and the noncompliance estimate of 8.5% to calculate the likelihood of a Lip Service vessel experiencing a PSC detention (2.85% per year) or DOJ prosecution (1.04% per year).

We then had to further specify some risks individually within the spreadsheet. For example, in the PSC detention risk for "Technician attendance", we applied a 50% reduction in risk, since only about 50% of MARPOL Annex I detentions involve equipment failure. In the DOJ prosecution risk "ECP development", we applied a 70% reduction in risk, since about 70% of DOJ prosecutions result in a sentence requiring an ECP.

Our estimates are based primarily on US data, since we had access to extremely granular data for this region[18]. However, enforcement of MARPOL Annex I in the United States, as regulated under the Act to Prevent Pollution from Ships ("APPS"), is higher than in other parts of the world, and a shipowner operating in less regulated waters would have a different cost benefit analysis.

We have also assumed that our Owners are risk neutral, meaning that we multiplied costs directly by their risk of occurring, rather than applying a multiplying factor to be risk averse or reducing factor to reflect a risk taker.

[16] Based primarily on the mode (1-10% violators) and median (11-20% violators) of the responses.
[17] The percentage of noncompliers is itself an interesting metric that warrants further research and analysis.
[18] Incorporation of enforcement activities in other regions would be a welcome addition to this study.

Detentions

A PSC detention generally starts with a deficiency during an inspection. The US Port State Control uses a number of different kinds of deficiencies to enforce APPS. According to the deficiency data, the most common Annex I related deficiencies are as follows:

System	Sub System	Component
Pollution Prevention/Response	Prevention Equipment	Oily Water Separator (15 ppm)
Documentation	Logs/Records	Oil Record Book
Pollution Prevention/Response	Prevention Equipment	Incinerator, Shipboard
Documentation	Certificates/Documents	IOPP Certificate
Documentation	Manuals/Policy Documentation	Transfer Procedures
Pollution Prevention/Response	Prevention Equipment	Overfill Devices
Documentation	Logs/Records	Transfer Equipment Test/Inspection Records
Operations/Management	Bilge/Bilge System Management	Control of Oil Mixtures
Engineering	Bilge Water Management System	Piping

Figure 6. Common US Port State Control deficiencies related to oily waste management, 2014-15

The average number of MARPOL Annex I related deficiencies over this period was 1,046 per year. Almost a quarter of these, on average 244 per year, were related to the OWS.

A deficiency might not have any costs to the shipowner as long as it is easily rectifiable, or can be rectified without any delay in the ship's activities. However, if a deficiency results in a detention, costs start to escalate quickly.

We assumed a 9-day detention, which is the average length of MARPOL Annex I related detentions[19] from the 2014-15 USCG data. During this time, the ship will lose its charter revenue. Where possible, a shipowner using this spreadsheet should enter their own charter data, but the spreadsheet automatically makes the following charter rate assumptions based on long-term averages from Clarkson's Shipping:

Vessel Type	Daily Charter Revenue
Bulk carrier	$0.1 x DWT
Containership	$0.25 x DWT
Passenger vessel	No loss of charter hire[20]
Other	$0.2 x DWT

Figure 7. Assumption for loss of charter revenue during a PSC detention

The shipowner will have to pay additional berthing costs during this time. The Owner may choose to either continue to pay for its port berth, or pay to re-locate to an anchorage at a lower cost but including costs for tug assistance and launches for various attendances on board. The spreadsheet

[19] From the start of PSC activity to removal of the detention.

[20] Passenger ships are rarely detained for OWS issues. Generally, crews are changed out, and the passenger ship continues to trade in order to prevent passenger refund/reassignment issues. While the passenger vessel will avoid loss of charter revenue, it is likely to incur other costs associated with detentions further down the line, when PSC follows up after the vessel has discharged its passengers.

has been built to choose the lowest of these two options based on the number of days of detention input in the "Assumptions" tab.

The shipowner will also incur costs of various attendances on board the vessel such as Class, Flag, and Owner's surveyors, and almost all MARPOL Annex I detentions will trigger an external ISM audit.

The various cost line items are detailed in the "Risks" tab of the spreadsheet analysis.

There is an additional risk in some markets (e.g. tankers) that a detention would result in a loss of a long-term lucrative charter, but this risk has not been included in the spreadsheet analysis.

DOJ Prosecutions

Not all detentions result in prosecutions, but if they do, costs will quickly escalate further.

The USCG will likely remove several crew members from the vessel. The Owner will have to continue to pay their crew wages and living expenses in the US. We have assumed four crew members (Chief Engineer, 2nd Engineer, whistleblower, and one material witness) would be detained for the length of the trial. The Owner will also have to incur a cost to fly out new crew members to replace the detained ones.

When the detention is lifted, the Owner often relocates the vessel to operate outside of US waters. This cost is a function based on daily bunkers burned and loss of charter revenue.

The Owner will also immediately start to accrue legal, management, and third party consultant fees. For the default spreadsheet, we have made the following assumptions about these costs based on industry input:

	Hourly Rate	Hours Per Month
Company attorneys	$400	60
Crew attorneys	$400	15 per crew member
Third party experts/consultants	$300	10
Management (in house)	$150	40

Figure 8. Assumptions for expected shipowner costs in case of DOJ prosecution

These were then multiplied by the expected number of months from discovery of non-compliance to sentencing, which is an average of 16 months based on the data aggregated in Appendix D. We have assumed that the crew prosecutions take approximately the same amount of time as the company prosecution.

In recent years, it appears that the DOJ has only pursued cases that they know will be successful, and therefore, we have assumed a conviction rate of 100% for our purposes. This can be altered in the "Assumption" tabs if data showing unsuccessful prosecutions is found.

For sentencing, we used the DOJ monthly bulletin data (see Appendix D) to find the average fine per vessel, $1,200,000, and the average community service payment per vessel, $340,000. There is a large amount of variability in both of these costs, and while there is a correlation between vessel size and fine size, it is impossible to predict what fine and community service payment a noncompliant vessel will receive beforehand, and therefore we rely solely on the averages.

Most sentences also involve an Environmental Compliance Plan. These costs are detailed in the spreadsheet analysis.

As mentioned in the Introduction to this report, we have chosen to exclude a number of potential costs of noncompliance that are difficult to quantify, such as reputational financial impacts and the fleet effect. However, we have retained line items for these costs in case data becomes available to quantify them.

ANALYSIS

The first finding of this study was that it is impossible to establish general conclusions about the cost of MARPOL Annex I that apply across all vessels. The ship type, size, propulsion system, area of operation and shipboard practices all significantly affect various costs of oily waste management, and therefore, the only possible way to address the question of Annex I costs is to take a ship-specific approach.

That being said, it is promising that for most of our example vessels, we were able to find oily waste management approaches for our Prudent Owners that were competitive with their Lip Service Owner counterparts.

We examine a few of these example vessels below, and show how one might alter the spreadsheet to realize cost savings for the Prudent Owner.

Example Vessels

We selected a number of different vessel types and sizes to test our spreadsheet on, which are shown below in Figure 9 with the overall Annex I cost results (including the risk of PSC and DOJ activities). The full spreadsheets are included in Appendix F for reference.

Example Vessel	Deadweight Tonnage	Main Engine Rating (kW)	Lip Service Owner Annual Compliance Costs	Prudent Owner Annual Compliance Costs
Tanker (small)	10,600	7,000	$40,500.00	$31,600.00
Containership	66,000	72,000	$56,900.00	$87,800.00
Bulk carrier	150,000	18,000	$49,600.00	$45,500.00
Passenger vessel	3,000 pax capacity	60,000	$41,200.00	$70,200.00
Tanker (VLCC)	280,000	45,000	$72,600.00	$68,600.00

Figure 9. Cost analysis outcomes for example vessels using default settings

Based on the above table, it is economically advantageous for our tankers and bulk carrier to comply with Annex I under the default spreadsheet settings, while it is economically advantageous for our containership and passenger vessel to pollute.

Note that our containership and passenger vessel have the highest main engine ratings, creating more sludge and bilge water generation. This results in very high disposal costs for these vessels. Our containership spends $47,000 annually on sludge disposal alone.

Interestingly, we can make a single change to the oily waste management approach to realize significant disposal savings: purchasing a more expensive incinerator with low energy requirements.

Recall that under our default settings, our Owners purchase a lower quality incinerator with a high energy requirement (250 L MGL per MT sludge). With an energy requirement this high, it is actually cheaper for our Prudent Owner to land their sludge to shore in certain areas. Under our default shore disposal cost ($70/MT), shore disposal is actually the cheaper option. However, if we buy a more expensive incinerator with a low energy requirement, the Owner will choose to incinerate their sludge instead, and avoid the costs of shore disposal. If the ship generates enough sludge to make up for the high capital cost of the incinerator, the latter approach makes more sense.

We tested this idea by changing the "Incinerator" line item in the "Costs" tab to $100,000, and the energy requirement to 10 L MGO per MT sludge[21]. In the case of the containership, this simple modification reduced the annual sludge disposal costs for the Prudent Owner from $47,000 annually (landed to shore) to less than $3,000 annually (incinerated), and only increased the annualized capital cost by about $9,000. The passenger vessel had similar cost savings from this approach.

We find that because of their high fuel consumption, and therefore high sludge generation, it is worthwhile for these vessels to invest in higher quality equipment that will save them money on sludge disposal downstream.

After making this modification to the sludge management approach for the containership and passenger vessel, the overall cost results are as follows:

Example Vessel	Deadweight Tonnage	Main Engine Rating (kW)	Lip Service Owner Compliance Costs	Prudent Owner Compliance Costs
Tanker (small)	10,600	7,000	$40,500.00	$31,600.00
Containership	66,000	72,000	$56,900	$53,200.00
Bulk carrier	150,000	18,000	$49,600.00	$45,500.00
Passenger vessel	3,000 pax capacity	60,000	$41,200.00	$47,400.00
Tanker (VLCC)	280,000	45,000	$72,600.00	$68,600.00

Figure 11. Cost analysis outcomes for example vessels after optimizing sludge management for select vessels

It is interesting to note that it is still cheaper to pollute for the passenger vessel. This is partially related to a cost that the passenger vessel does not incur as a noncomplier – the risk of loss of charter revenue during a detention, and lack of relocation risk. However, it is also important to remember that there are cost considerations that are particularly important to passenger vessels that are not included in our analysis – in particular, reputational financial impacts are an important cost consideration for this industry. We also note that passenger vessels tend to have higher fines and more expensive ECPs in the case of discovery and prosecution, although this has not been built into our model.

These are only example vessels, and there is a lot to be gained by playing with the spreadsheet directly to look at various cost tradeoffs, and assess pollution incentives and dis-incentives for various vessel types and sizes.

Some example opportunities for cost savings for an individual vessel to explore might be:

- Investing in training instead of top-of-the-line equipment
- Investing in top-of-the-line equipment to reduce disposal costs (e.g. the incinerator solution discussed above)
- Running "dry bilges", and reducing equipment costs
- Use of emerging technologies such as bio-based products and straight filters
- Optimizing oily waste disposal schedules, so that wastes are discharged at the lowest cost facilities[22]

[21] In reality, top of the line incinerators require fuel only to start the system.
[22] This effort can be assisted as an industry by building out IMO's GISES database, and specifically making sure that ports provide details on their waste disposal costs online.

It is worth noting that disposal costs tend to be a large proportion of the total Annex I costs. Therefore, incorporating disposal costs into general port fees, effectively making the disposal cost the same for Prudent Owners and Lip Service Owners, would change the cost analysis significantly, removing a large financial incentive for polluters.

Limitations

Ship-Specific Approach

We were tasked with providing a cost analysis of compliance with MARPOL Annex I. It quickly became apparent that taking a general cost analysis approach would be impossible, due largely to the ship-specific nature of the costs associated with this regulation.

Therefore, the cost analysis instead began to take the form of the editable spreadsheet found in Appendix A. However, even this spreadsheet can only serve as the starting point for a specific vessel's costs, since even sister vessels could have drastically different cost considerations.

For example, imagine that one vessel (Vessel 1) serves a direct route between two close European ports, while her sister (Vessel 2) is in the spot market, serving a wide variety of ports around the world.

Vessel 1 might have significantly lower Annex I costs than Vessel 2, since Vessel 1 can dispose of their wastes at known ports in an area of the world with relatively low disposal costs. Since Vessel 1 has a known route, they can also optimize their disposal schedule – for example, if one of their ports is in Russia, where sludge disposal is often fully incorporated into port fees, they might choose to never dispose of their wastes at the other port, as long as they have sufficient sludge tank capacity to get back to the Russian port. If they have cheap disposal options, this also frees them from having to make expensive investments in top-of-the-line equipment. Vessel 1 may actually choose to forgo an incinerator entirely. Since Vessel 2 does not know what their future disposal options are, a Prudent Owner might be forced into expensive discharge rates in the face of uncertainty, and additionally must invest in expensive equipment in case no disposal options exist.

The above example shows that the cost analysis is very specific to the situation of the ship, and that simply entering the deadweight tonnage, main engine rating, and vessel type into the spreadsheet will not be sufficient to result in an accurate cost analysis.

We hope that the spreadsheet can serve as a framework for a specific ship and shipowner to look at their MARPOL Annex I costs, make alterations according to their specific situation, and then make decisions on their oily waste management approach.

Percentage of Polluters

Our analysis rests on an inherently elusive number, which is the percentage of polluting vessels. We needed to come up with an estimate of this percentage in order to determine the risk of a polluting vessel getting caught. Our ultimate estimate (8.5%) is based on Port State Control data and the results of the MAX1 Studies Survey from 2015. This is discussed in more detail on page 15 of this report. However, it is important to note that small changes in this number can have a significant impact on the cost analysis, and the percentage reached is only our best estimate.

Excluded Benefits

We also note that there are a number of secondary benefits arising from compliance with MARPOL Annex I that are not captured in this analysis. For example, training crews in Annex I compliance would likely have carry on effects for other current and upcoming environmental regulations, and can also be combined with other crew training initiatives, such as crew safety, resulting in reduced legal costs for shipowners.

We have also used a bilge water generation equation that results in a relatively high estimate. Especially for crews who actively manage their bilge water generation, the overall amount of oily waste generated could be significantly lower than the default spreadsheet estimates.

Finally, as mentioned previously, we did not include any "externality" benefits in our analysis, such as the compliance benefit to the environment and global population, and the psychological benefits to the crew from avoiding prosecution and potential jail time[23].

Averaging Costs

The costs included in this analysis are primarily estimates and averages, and cannot fully capture every nuance of ship operations. Economic analysis is a form of predicting the future, but can only predict average outcomes rather than specific ones.

For example, there is a large range of outcomes for the length of a DOJ prosecution, the number of crew members being prosecuted, and the ultimate size of the fine and community service payment. The spreadsheet has only taken the average of each of these factors, and applied a risk of receiving each average cost. More granularity could be added to the prediction by associating a vessel size or type with a larger or smaller fine, but these would still be averages, and ultimately it is impossible to predict the size of the fine that would be received by a violating ship.

We also note that the above approach of averaging prosecution costs means that the spreadsheet is not very applicable to very small vessels[24], since these vessels would undoubtedly receive much lower costs in the face of PSC/DOJ prosecutions, but the prosecution costs have not been scaled for vessel size. Theoretically, the spreadsheet could be altered to accommodate small vessels, but this would require significant data analysis and revisions to the spreadsheet.

Areas for Future Research

This study only applies to MARPOL Annex I oily waste management, but may serve as a guideline for future cost analyses for compliance with other MARPOL initiatives.

The study and spreadsheet could also benefit greatly by adding more cost data. Specifically, adding excluded benefits of compliance (such as inclusion of enforcement activities in other parts of the world) would add accuracy and more flexibility to the model.

We would also find it interesting to expand the costs examined to include those of the general public, and particularly shipboard crews. While aligning shipowner incentives are an important part of

[23] It would be interesting to conduct a similar cost analysis from the perspective of the crew, in order to show the motivations of polluting crew members.
[24] It would also underestimate Lip Service costs for very large vessels.

achieving full compliance, ultimately compliance rests with ships' crews. If the incentive structure is built so that it is to crews' advantage to maintain MARPOL compliance, we would expect reductions in pollution as well.

CONCLUSIONS

We were asked to look at costs for compliance versus noncompliance with MARPOL Annex I. While it is not possible to arrive at a generalized conclusion for whether it is economically beneficial to comply with Annex I, it is apparent based on the data and analysis that there are significant cost savings available to a prudent shipowner to reduce their Annex I costs, and that these savings can often put them at a level playing field – or even at an economic advantage – with their noncompliant counterpart.

While a noncompliant vessel must incur certain unavoidable costs and continually runs a risk of large detention and prosecution costs, a compliant vessel has many options available to minimize their oily waste management costs.

We encourage prudent shipowners to study and optimize their costs, provide transparent and well-reasoned approaches to their crews, and clearly and honestly communicate with PSC officials with regard to their environmental compliance approach.

If compliant shipowners do their homework, and enforcement agencies continue to do their part to find and financially punish noncompliers, our data indicates that compliance can outcompete noncompliance in many cases.

APPENDIX A: Cost Spreadsheet

The cost analysis was conducted in Microsoft Excel. The full, editable spreadsheet can be found at:

http://www.martinottaway.com/technical-documents/MAX1-Studies/cost-analysis

There are three main sections of the Cost Spreadsheet:

1. "Costs" – equipment and operational costs to comply with MARPOL Annex I and/or optimize oily waste management
2. "Risks" – quantification of potential Port State Control and Department of Justice costs in the case of non-compliance
3. "Assumptions" – inputs and assumptions relied upon for the cost analysis, including ship characteristics, capital costs, operating costs, and PSC and DOJ activities

The entire spreadsheet is customizable, but the equations have been specifically built in order to easily handle changes to the bright yellow boxes in the Assumptions tab.

The overall costs of compliance are housed at the bottom of the Costs tab, under the Total section.

APPENDIX B: Industry Data

The following individual capital and operating cost data points were collected from industry sources and used to inform our Cost tab in our Cost Spreadsheet (Appendix A).

Type	Cost
OWS - 5m3	$ 35,000.00
OWS	$ 45,000.00
OWS - 5m3	$ 140,000.00
White box	$ 28,000.00
OWS installation (5)	$ 140,000.00
OWS annual costs	$ 7,250.00
OWS - 2m3	$ 120,000.00
OWS - 1m3	$ 95,000.00
OWS commissioning/training	$ 4,000.00
OWS - 2.5m3	$ 18,000.00
OWS installation (2.5)	$ 11,000.00
OWS	$ 15,000.00
OWS installation	$ 10,000.00
OWS coalescer element replacement (1)	$ 175.00
OWS media change (1)	$ 680.00
OWS	$ 100,000.00
OCM	$ 30,000.00
OWS - 1m3	$ 13,350.00
OWS media change (1)	$ 453.00
OWS maintenance costs per MT (1)	$ 2.50
OWS operating costs per m3	$ 3.00
OWS operating costs per m3	$ 3.50
Incinerator + tankage	$ 10,200.00
Bilge water inc. capacity	$ 28,500.00
IBTS system	$ 15,900.00
OCM for CDT	$ 9,000.00
OCM	$ 2,400.00
E/R improvements	$ 13,500.00
OWS	$ 15,000.00
OWS installation (materials)	$ 3,000.00
OWS installation (mechanical)	$ 10,000.00
OWS installation (electrical)	$ 3,000.00

OWS commissioning	$	3,000.00
OWS install class attendance	$	3,000.00
OCM calibration/replace sensor	$	2,000.00
OCM calibration/cert	$	742.50
OCM calibration/cert	$	600.00
OCM	$	2,400.00
OCM new sensor	$	1,450.00
OCM new cell	$	1,809.00
OWS new media set	$	467.00
OWS new media set	$	500.00
MARPOL equip spares	$	10,000.00
MARPOL equip service eng. & class attendance	$	8,000.00
Yearly disposal of sludge/garbage	$	6,000.00
ENVIRO notation	$	36,000.00
OCM calibration	$	550.00
Truck sludge disposal in NJ, USA (per m3)	$	100.00
Shore sludge disposal in Ecuador (per MT)	$	50.00
Shore sludge disposal in Costa Rica (per MT)	$	61.00
Shore sludge disposal in Guatemala (per MT)	$	92.00
Shore sludge disposal in St. Petersburg, Russia	$	-
Shore sludge disposal in China	$	-
Shore sludge disposal in Canada (per m3)	$	231.00
Shore sludge disposal in Rotterdam (per m3)	$	27.00
Shore sludge disposal in Singapore (per m3)	$	126.00
Shore sludge disposal in Ecuador (per m3)	$	27.00
Shore sludge disposal in Philippines (per m3)	$	53.00
Shore sludge disposal in China	$	(50.00)
Bilge water disposal in China	$	-
Oily waste disposal Canada (per m3)	$	135.00
Oily waste disposal costs - high range	$	528.00
Truck sludge disposal in USA	$	3,000.00
Sludge incineration (MGO/MT sludge)	$	350.00
Barge de-slopping in Singapore (per cm3)	$	21.00
Crew training conference (per person)	$	1,250.00
Crew training conference (per person)	$	250.00
Crew training conference (per person)	$	500.00

APPENDIX C: Port State Control Data

The following data is a subset of the United States Coast Guard "Vessel Controls" database. It includes environmental protection vessel detentions from 2014-2015 related to MARPOL Annex I compliance.

This data was used to determine the frequency of MARPOL Annex I related detentions, and to determine the average length of detention.

Activity Start Date	Imposed Date	Removed Date	Restriction Description
2/1/2014	2/1/2014	2/4/2014	PSCO established clear grounds for believing the crew are not familiar with essential shipboard procedures relating to the prevention of pollution by oil. C/E was not able to demonstrate proper operation of the OWS to the attending PSCO.
7/7/2015	7/14/2015	8/5/2015	Vessel must demonstrate proof that the oily water separating equipment meets IMO standards to the satisfaction of the attending Coast Guard Marine Inspector.
2/19/2015	2/21/2015	2/23/2015	Ensure proper operation of OWS and OCM to the satsifaction of classification society and USCG PSCO"s
4/21/2015	4/21/2015	4/23/2015	Replace overboard discharge valve on OWS w/ valve capable of being locked or secured prior to use of OWS
6/27/2015	7/3/2015	7/5/2015	A PSC safety exam was conducted. It was found that the vessel did not comply w/ the provisions of the: MARPOL & ISM conventions & was substandard in the following areas: Master or crew is not familiar with essential shipboard procedures relating to the prevention of pollution by oil. (MARPOL I/11); The SMS has not been maintained IAW the provisions of the ISM Code. (SOLAS 2014 IX/5, ISM Code A.2). See activity 5165211 narrative for details. 05JUL15: Recieved, reviewed & accepted class report from NKK.
2/19/2014	2/21/2014	2/24/2014	Your vessel is to remain in the Columbia River system while the Coast Guard verifies compliance with MARPOL Annex I regulations. Any movement within the port shall be coordinated through the Port State Control office at MSU Portland.
1/16/2015	1/16/2015	1/26/2015	A PSC Safety exam was conducted. It was found that the vessel did not comply with the provisions of the MARPOL convention, and was substandard in the following areas: Oil transfers were not being logged as required by the vessel's SMS The oily water separator could not discharge below 15 ppm The sludge system was permanently piped to the oily water separator See narrative for more details. 26JAN15: Received, reviewed, and accepted class report from DNV satisfying outstanding requirements related
8/4/2014	8/4/2014	8/8/2014	Vessel detained under the Authority of MARPOL ANNEX 1
1/3/2015	1/3/2015	1/27/2015	Vessel has been detained due to MARPOL violations. See activity #5043527 for details.
11/16/2014	11/17/2014	11/21/2014	Vessel detained after crew member reported illegal discharges of oil and oily waste from engine room. See activity 5024394 for details.
7/7/2015	7/14/2015	8/5/2015	Vessel is prohibited from leaving any port in Sector Honolulu COTP Zone until vessel can demonstrate proper oil & oil waste management and proper recordkeeping for oil & oil waste management.
1/23/2014	1/23/2014	1/24/2014	230442Z JAN 14 - COTP NO. 0047-14 - Due to Crew Concerns, vessel is restricted to LOWER MISSISSIPPI RIVER pending an ADMINSTRATIVE INVESTIGATION into potential violation of MARPOL ANNEX I and the Act to Prevent Pollution from Ships.
7/10/2015	7/10/2015	8/5/2015	Prove proper engine room waste management practices and recordkeeping. Prove proper operation of the OWS.

7/24/2014	7/24/2014	7/30/2014	Vessel is undergoing a MARPOL expanded exam under the authority MARPOL (2011) Annex 1 for the deficiencies as outlined on the CG-5437b dated 24 July 2014. The vessel will remain detained in this port until all of the deficiencies are corrected to the satisfaction of the Administration, and the Coast Guard Captain of the Port.
6/25/2014	6/27/2014	7/1/2014	Vessel detained for oil record book.
1/28/2014	1/28/2014	2/3/2014	A PSC safety exam was conducted. It was found that the vessel did not comply with the provisions of SOLAS/MARPOL/ISM Code, and was substandard in the following areas: proper maintenance operation of the OWS, proper testing procedures of the OWS. See narrative for more details.
4/21/2015	4/21/2015	4/28/2015	Vessel Detained under IMO MARPOL Annex I. See the narrative for details.
10/27/2014	10/27/2014	10/31/2014	Vessel's oily water seperator is capable of discharging bilge water exceeding 15ppm due to inoperable oil content meter.
6/29/2015	6/29/2015	7/28/2015	Vessel was issued an IMO Detention due to the inability to stop the flow of the OWS when the effluent exceeded 15ppm.
3/5/2015	3/6/2015	3/8/2015	Vessel is under IMO Detention until cleared by the USCG. See Misle Activity 5074028 for more information.
1/23/2014	1/24/2014	1/25/2014	A PSC safety exam/ISPS II exam was conducted. It was found that the vessel did not comply with the provisions of MARPOL, and was substandard in the following areas: vessel did not maintain an oil record book.
4/23/2015	4/24/2015	4/25/2015	Any Ship of 10,000 Gross Tonnage and above shall be fitted with oil filtering equipment complying with paragraph 7 of this regulation. The installed MEPC 107(49) oil filtering equipment failed to process oily bilge water from the vessel's bilge water remaining in the tank at each attempt to operate the oil filtering equipment it failed with error. Ship detained to the satisfaction of the RO/RSO and Coast Guard.
5/14/2014	5/15/2014	5/21/2014	Vessel has been detained under the authority of MARPOL Annex I/15.1 for the deficiencies outlined in CG-5437. The vessel will remain detained in this port until all of the deficiencies are corrected to the satisfaction of the Administration, and the Coast Guard Captain of the Port.
11/12/2014	11/12/2014	12/5/2014	Detained under MARPOL Annex I/ 7.2.
7/24/2014	7/24/2014	7/30/2014	Vessel has been detained under the authority MARPOL (2011) Annex 1 or the deficiencies as outlined on the CG-5437b dated 24 July 2014. The vessel will remain detained in this port until all of the deficiencies are corrected to the satisfaction of the Administration, and the Coast Guard Captain of the Port.
2/6/2015	2/7/2015	2/8/2015	Vessel's oily water seperator is inoperable.
11/28/2014	11/29/2014	11/29/2014	Oily water separator was inoperable.
11/28/2014	11/29/2014	11/29/2014	Safety Management System did not address maintenance and testing of the OWS.
7/15/2015	7/16/2015	7/26/2015	A PSC safety exam was conducted. It was found that the vessel did not comply with the provisions of the: MARPOL convention and was substandard in the following area(s): oily water separator operation and crew familization of oily water separator. 26JUL15: Received, reviewed and accepted class report from NIPPON KAIJI KYOKAI satisfying outstanding requirements related to the detention. Approved the release from detention. See narrative for details.
1/30/2014	1/31/2014	2/4/2014	Vessel is detained under Baltimore COTP authority. Evidence gathered during exam and witness statements attest to illegal discharges of oil from engine room via economizer soot collection tank.
4/21/2015	4/21/2015	4/30/2015	Crew did not know how to test or run OWS. Crew to demonstrate proper operation of OWS prior to sail.
4/1/2015	5/6/2015	5/7/2015	During exam found inoperable Oily Water Seperator. Demonstrate proper operation to attending MI.
3/27/2015	3/27/2015	4/6/2015	Vessel has been detained under MARPOL Annex I for suspected bypass of bilge piping.
8/5/2014	8/5/2014	8/11/2014	The vessel must have Flag or Class on their behalf, attest to the proper operation of the OWS. Once the OWS is working, the crew must be able to show competency in using it.
12/23/2014	12/24/2014	12/28/2014	Vessel detained for inoperable OWS and incinerator.

3/25/2015	3/25/2015	3/27/2015	Vessel detained by Sector Baltimore PSC after crew demonstrated lack of familiarity with Oily Water Separator and Oil Content Meter operation. See activity 5090083 for details.
1/9/2015	1/16/2015	1/20/2015	Remain moored at the vessel's current location in Dutch Harbor, AK until the investigation is completed to the satisfaction of the Captain of the Port, Western Alaska
9/2/2015	9/2/2015	9/8/2015	In view of the severity of the noncompliance, the vessel is hereby detained in port under the provisions of SOLAS.
2/12/2014	2/12/2014	2/12/2014	Vessel must cease operations in COTP Ohio Valley zone until requirements of COTP Order are met. COTP Order is attached in activity documents.
2/12/2014	2/12/2014	2/12/2014	Vessel must cease operations in COTP Ohio Valley zone until requirements of COTP Order are met. COTP Order is attached in activity documents.
3/17/2015	3/19/2015	3/23/2015	Vessel is detained until deficiencies identified during port state exam have been corrected.
7/24/2014	7/24/2014	7/30/2014	Vessel has been detained under the authority 74 SOLAS IX/3.1 for the deficiencies as outlined on the CG-5437b dated 24 July 2014. The vessel will remain detained in this port until all of the deficiencies are corrected to the satisfaction of the Administration, and the Coast Guard Captain of the Port.
8/4/2015	8/5/2015	8/9/2015	Remain in Port Hueneme, CA until expanded MARPOL examination is completed and any hazardous conditions discovered as a result, are corrected.
4/24/2014	4/24/2014	4/25/2014	240520Z APR 14 COTP 0242-14 After notification that your vessel experienced a discharge of oil at MM 100.2 LMR AHP, your vessel is restricted to the Nashville Avenue Warf, MM 100.2 LMR AHP. This restriction is in effect until your vessel meets the following requirements and is cleared by my office: a. Pollution removal is completed to the satisfaction of the Federal On Scene Coordinator (FOSC) and a Coast Guard investigation is complete with regards to the cause of the spill. 251540Z APR 14 – Cleared

APPENDIX D: Department of Justice Data

The following list of prosecution and sentencing data is sourced from the United States Department of Justice monthly bulletins from 2007-2017.

Discovery Date	Sentencing Date	Fine	Comm. Service Payment	Probation + ECP?	Conviction	Notes
6/1/2015	1/11/2017	$ 2,025,000.00	$ 675,000.00	5 yr probation	Conspiracy, violating APPS, false statements, 2 counts obstruction of justice, 4 counts witness tampering (9 counts total)	Fines shared between two companies (operator and corporate owners); both barred from US ports until financial penalty paid; 10 mt sludge; magic pipe; bypass OWS; falsified ORB; discovery Wilmington NC
8/23/2013	12/1/2016	$30,000,000.00	$10,000,000.00	8 ships under ECP for 5 yrs	7 charges	Dumping; dilution; clean water through OCM; greywater overflows (due to faulty internal floats from fat/grease/food from galley) to bilges & re-pumping to GW tanks; magic pipe; financial motive related to shore side disposal in UK
8/5/2014	11/23/2016	$ 500,000	$ 250,000.00		Violating APPS, failing to maintain ORB	ORB omits disposals of oil residue, overboard discharges of oil and oily mixtures, and disposals of machinery space wastes. Discovery in Port of San Diego.
7/1/2015					Four APPS violations (33 USC 1908(a)); fail to maintain accurate ORB; illegal discharge of BW	Sept 29, 2016 "information filed charging" Pacific Breeze
1/1/2015	8/1/2016				Crew guilty plea: discharge oily waste thru sewage system; falsify ORB & destroy sounding log	
7/8/2016	8/16/2016	$ 275,000.00		Probation only	8,400 gallons of bilge water unaccounted for in ORB + 5,400 in void space not doc in ORB	
2/1/2016	4/1/2016	$ 750,000.00	$ 200,000.00	Yes	500 gal BW overboard	
11/3/2015	7/25/2016	$ 800,000.00	$ 200,000.00	Yes	APPS violation for failure to maintain accurate ORB	BW discharges Feb 2015 - Oct 2015; Discovery in Duluth
10/1/2015	6/20/2016				Owner, oper, 2 eng each guilty 3 counts: APPS, false statements, falsification of records violations	5,000 gal BW overboard while OWS inoperable and concealed from USCG
	11/1/2015	$ 2,000,000.00	$ 500,000.00	Yes	Conspiracy, APPS, obstruction, witness tampering	20,000 gal BW overboard; discharge sludge overboard in garbage bags
3/1/2015					APPS violation	Disc in Pensacola; Jan-Mar 2015 bypass OWS
	6/3/2015	$ 600,000.00	$ 150,000.00	Yes	APPS violation	Discharge 2,000 gal BW in Alaska; false records; company already on env probation

9/5/2014	5/26/2015	$ 675,000.00	$ 125,000.00	Yes	APPS and Clean Water Act violations	Disc in Portland OR; 5,000 gal BW discharge
1/1/2014	1/30/2015	$ 1,350,000.00	$ 450,000.00	Yes	APPS ORB violation	Discharged oily wastes overboard; Baltimore disc
4/1/2014	3/5/2015	$ 2,150,000.00	$ 600,000.00		3 APPS violations for offenses in 2013/14	"Magic hose" to bypass OWS; whistleblowers
1/18/2014	10/2/2014	$ 800,000.00	$ 100,000.00	Yes	APPS and obstruction violations	Bypass OWS; Mississippi River, discharged 'several metric tons' of oily bilge waste
	12/19/2014	$ 8,200,000.00	$ 4,000,000.00	4 yr prob + ECP	Five APPS charges (33 USC 1908(a)), 1 violation of NANPCA, 2 violations of PWSA	Drill ship & drilling unit in Alaska; discharge waste water overboard, oily wastes to ballast water tanks, failed to maintain accurate ORB; Noble must implement env management system for all MODUs
	7/24/2014	$ 500,000.00		3 year probation	APPS violation	Discarged 34 metric tons of oily bilge water and waste sludge
3/28/2013	5/20/2014	$ 375,000.00	$ 125,000.00	2 year probation	APPS violation	Illegal overboard discharges of oil sludge, piping arrangement had been illegally modified, fake oily waste disposal receipts, contradictory ORB entries
5/1/2012	7/23/2013	$ 7,800,000.00	$ 2,600,000.00	4 year probation and ECP	APPS and obstruction violations	King Emerald: illegal discharging of bilge waste and sludge. Nordic Passat: illegal discharges made through ship sewage system, sludge in ship cargo tanks. Cape Maas: OWS pumping overboard without use of OCM. Cape Taft: OWS flushed with fresh water, ORB altered.
1/1/2012		$ 1,000,000.00	$ 200,000.00	5 year probation	2 obstruction violations, 1 APPS violation for concealing the illegal dumping of oil at sea	Consequences of violations split jointly and severally between the two companies and operator/owner of Susan K. Bypassed OWS, discharged bilge wastewater overboard. Chief engineer falcified ORB.
	7/25/2012	$ 1,000,000.00	$ 100,000.00	Yes	APPS violation, obstruction, and a PWSA violation	Illegal overboard discharges of sludge and oily water and failing to notify authorities of cracks found in ballast tanks. Bypass hose used to pump contents of bilge tank, bilge oil tank, and sludge tank overboard. Falsified ORB.
9/1/2011	5/30/2012	$ 1,000,000.00	$ 200,000.00	Yes	APPS violation for failure to properly maintain ORB	Overboard oily bilge waste discharge. Mobile disc. Bypass pipe connecting bilge system to ballast system July- August 2011.
4/1/2011	3/27/2012	$ 1,750,000.00	$ 250,000.00	3 year probation	APPS and obstruction violations for routine illegal discharge of oily bilge waste	Falsified ORB
8/1/2011	5/5/2012					APPS violation for false entries in ORB. Discharged oily bilge water without OWS use.

2/1/2011	1/25/2012	$ 650,000.00	$ 550,000.00	Yes	APPS, obstruction, and false statement violations	Illegal dumping of sludge, plastics, and oily waste water. Baltimore disc. Discharged waste oil overboard via bypass equipment. Plastic bags filled with oily rags thrown overboard.
8/1/2011	11/15/2011	$ 500,000.00	$ 150,000.00	Yes	Obstruction and APPS violations for illegal overboard discharge of oily bilge waste	Falsified ORB; sludge discharge; tricked pollution control equipment to facilitate illegal discharges.
	11/2/2011	$ 375,000.00	$ 375,000.00	Yes	APPS and false statement violations for illegal discharge of oily waste	June - October 2011: tricked oil content meter (not recorded in ORB).
5/10/2010	9/8/2011	$ 600,000.00	$ 200,000.00	3 year probation	APPS and false statement violations for presentation of false ORB to CG	Consequently required to implement a comprehensive advanced training and verification program to continuously monitor vessel operations and train crewmembers to prevent pollution from any ship it operates. San Juan, Puerto Rico disc. Discharged oily bilge waste January - May 2010. Bilge waste discharged without being processed or monitored. Falsified ORB.
8/1/2010	10/21/2011					Pleaded guilty to one count of failure to maintain an accurate oil record book, and one count of failing to submit reports to the NBIC. Sensor on OWS filled with oily waste. Compressed airline in engine room filled with oily waste.
11/1/2010	8/18/2011	$ 600,000.00	$ 100,000.00	5 year probation and ECP	APPS and false statement violation for unlawful discharges of oily waste and failure to record discharges in ORB	Puerto Rico disc. Used emergency bilge discharge system to pump oily waste into ocean.
	7/28/2011	$ 750,000.00	$ 250,000.00	5 year probation	Obstruction, APPS oil record book violations, and Ports and Waterways Safety Act violations for failing to notify the Coast Guard of a hazardous condition on the M/V Americana	Bypass pipe. Falsified ORB. Inoperable generator and a hole between a fuel tank and a ballast tank discovered while in New Orleans Port in November 2011.
6/1/2010	6/7/2011	$ 750,000.00	$ 150,000.00	5 year probation	APPS ORB violation and violation of the Ports and Waterways Safety Act for failing to report a hazardous condition on board	June - September 2010: bypassed pollution prevention equipment to discharge oily bilge water. Port of Houston disc.
8/18/2010	3/31/2011	$ 750,000.00	$ 250,000.00	2 year probation and ECP	Making false statements, knowingly failing to accurately maintain an oil record book, and knowingly discharging oily bilge waste without using proper pollution prevention equipment	American Samoa disc.
5/3/2010	2/23/2011	$ 2,400,000.00		Yes	APPS violation and obstruction	Baltimore disc. Bypass pipe. Falsified ORB.

	11/4/2010	$ 1,750,000.00	$ 350,000.00	Yes	APPS violation	July - September 2005: Oily waste water stored in bilge water holding tank. Under contract with NSF.
10/1/2009	12/2/2010	$ 800,000.00	$ 100,000.00	ECP	False statements and APPS violation for failure to accurately maintain ORB	Tampa disc. Bypass hose. October 10 -October 21 2009: oily bilge waste transferred to aft port peak ballast tank. Prior to October 21, 2009 a large quantity of oily waste was discharged from ballast tank.
5/1/2010	9/29/2010	$ 525,000.00	$ 125,000.00	Yes	Violations of the APPS and the Oil Pollution Act	Bypassed the OWS and illegally discharging oily waste December - May 2010. Falsified ORB. New Orleans disc. Oil leak since April 2010.
10/1/2009	9/9/2010	$ 3,000,000.00		3 year probation	Obstruction, false statements, APPS violation	Falsified ORB. "Dummy" sounding tube.
2/1/2010	7/30/2010	$ 750,000.00	$ 100,000.00	Yes	False statement and APPS violation	Bypass hose. Oakland, California disc. Faulty OWS and incinerator. Falsified ORB.
	12/9/2009	$ 2,700,000.00	$ 100,000.00	3 year probation	2 APPS violations, a false statement violation, a Ports and Waterways Safety Act violation and a Nonindigenous Aquatic Nuisance Prevention and Control Act violation	Breach in the outer skin of the vessel and fuel oil leaks into the forepeak ballast tank. Falsified ORB. Falsified ballast log.
2/1/2009	10/21/2009	$ 1,000,000.00	$ 250,000.00		3 APPS violations for failing to maintain ORB	Bypass pipe December 2006 to February 2009. Discovery in Texas City.
	7/22/2009	$ 2,080,000.00		Yes	Consipiracy, falsification of records, false statements, obstruction, and an APPS violation	Discovery in St. Croix. Bypass pipe 2007-2008.
11/1/2007	3/13/2009	$ 1,000,000.00		5 year probation and ECP	APPS ORB violation and false statements	Bypass hose. Corpus Christie discovery.
2/1/2008	3/10/2009	$ 1,000,000.00	$ 400,000.00	Yes	APPS violation and false statement	Bypass OWS between Los Angeles and Chile.
10/1/2007	2/24/2009	$ 1,350,000.00	$ 400,000.00	Yes	Conspiracy and for falsifying and failing to properly maintain ORB	Tampa discovery. Bypass hose June 2007 to February 2008.
7/3/2008	1/13/2009	$ 1,300,000.00		Yes	Conspiracy, APPS, obstruction and false statement violations	Discovery in Philadelphia.
5/26/2008	10/22/2008	$ 500,000.00	$ 250,000.00	Yes	Conspiring to violate APPS and falsifying ORB	Discovery in Oakland. Bypass between July 2007 and May 2008.
8/17/2007	7/9/2008	$ 1,200,000.00	$ 500,000.00	Yes	APPS and false statement violations	Houston Discovery. Bypass hose.
10/7/2007	7/27/2008	$ 500,000.00	$ 280,000.00	3 year probation	ORB violations	Illegal bypass October 5-18 2007.
	6/19/2008	$ 3,250,000.00	$ 1,500,000.00	ECP	Conspiracy, APPS and false statement violations	Regularly dumped oil-contaminated bilge water overboard between March and June of 2006.

3/6/2002	6/23/2008	$ 250,000.00			APPS ORB violation	Bypass hose and falsified ORB.
4/1/2006	4/4/2008	$ 1,700,000.00	$ 400,000.00	4 year probation and ECP	APPS violation and two false statement violations	
5/14/2004	10/15/2007	$ 500,000.00	$ 2,000,000.00	Yes	APPS violation and failing to maintain ORB	Oily sludge from the engine room leaked en route to a holding tank on deck as the ship left an Alaskan port. Rain then washed the oil down the side of the ship and into the ocean.
10/2/2003	6/20/2007	$27,800,000.00	$ 9,200,000.00	Yes	APPS, false statement, conspiracy and obstruction violations	Boston discovery. Flushing oil sensing equipment with freshwater. Bypass hoses. Falsified ORB. 40,000 gallons of sludge and oily waste discharged from one vessel and approx. 2,600 gallons discharged from another in the Exclusive Economic Zone off the coast of North Carolina. Violations occurred between June 2001 and March 2006.
	1/29/2007	$ 1,000,000.00	$ 250,000.00		APPS violation for misleading US Coast Guard	Inoperable OWS and falsified ORB. Bypass pipe. Delaware discovery.
9/1/2003	1/24/2007	$ 1,000,000.00	$ 500,000.00	Yes	APPS violations for the deliberate overboard discharge of hundreds of thousands of gallons of oil contaminated bilge waste from four of its ships through the use of a bypass pipe	Admitted to circumventing the oily water separator (“OWS”) on four giant “car carrier” ships used to transport vehicles. Falsified ORB.
10/5/2006	1/23/2007	$ 500,000.00	$ 250,000.00	4 year probation and ECP	Failing to maintain an accurate oil record book in an attempt to conceal illegal discharges of oily sludge directly into the ocean	Bypass hose discovery in Vancouver, Washington.

APPENDIX E: Deficiencies Data

Below is a full list of USCG MARPOL Annex I related deficiencies used over the period from 2014-2015.

System	Sub-System	Component
Communications	Alarms/Indicators	Bilge Alarm
Documentation	Certificates/Documents	IOPP Certificate
Documentation	Logs/Records	Declaration of Inspection
Documentation	Logs/Records	Oil Record Book
Documentation	Logs/Records	Transfer Equipment Test/Inspection Records
Documentation	Manuals/Policy Documentation	Emergency Instructions
Documentation	Manuals/Policy Documentation	Operations Manual (Incinerator)
Documentation	Manuals/Policy Documentation	Transfer Procedures
Documentation	Markings/Placards	Oil Discharge Placard
Documentation	Safety/Response Plans/Programs	SOPEP
Documentation	Safety/Response Plans/Programs	Vessel Response Plan
Engineering	Bilge Water Management System	Hose
Engineering	Bilge Water Management System	Interface Detector
Engineering	Bilge Water Management System	Manifold
Engineering	Bilge Water Management System	Not Installed
Engineering	Bilge Water Management System	Not Operational
Engineering	Bilge Water Management System	Piping
Engineering	Bilge Water Management System	Pump
Engineering	Bilge Water Management System	Strainer
Engineering	Bilge Water Management System	Valve
Engineering	Bilge Water Management System	Vent
Fire Fighting	International Shore Connection	Bolts
Fire Fighting	International Shore Connection	Gasket
Fire Fighting	International Shore Connection	Not on Board
Operations/Management	Bilge/Bilge System Management	Control of Excess Water
Operations/Management	Bilge/Bilge System Management	Control of Oil Mixtures
Operations/Management	Pollution	Control of Discharge of Oil
Operations/Management	Pollution	Retention of Oily Mixture
Pollution Prevention/Response	Prevention Equipment	Bilge Monitor
Pollution Prevention/Response	Prevention Equipment	Cargo Monitor/Control System
Pollution Prevention/Response	Prevention Equipment	Coamings
Pollution Prevention/Response	Prevention Equipment	Drains/Scuppers (means of closure)
Pollution Prevention/Response	Prevention Equipment	Fixed Containment
Pollution Prevention/Response	Prevention Equipment	Incinerator, Shipboard
Pollution Prevention/Response	Prevention Equipment	Oily Mixture Discharge Fixed Piping System
Pollution Prevention/Response	Prevention Equipment	Oily Mixture Discharge Pump
Pollution Prevention/Response	Prevention Equipment	Oily Residue (sludge/slop) Tank
Pollution Prevention/Response	Prevention Equipment	Oily Water Separator (15 ppm)

Pollution Prevention/Response	Prevention Equipment	Overfill Devices
Pollution Prevention/Response	Prevention Equipment	Portable Containment
Pollution Prevention/Response	Prevention Equipment	Standard Discharge Connection
Pollution Prevention/Response	Response Equipment	Non-sparking Hand Scoops/Shovels/Buckets
Pollution Prevention/Response	Response Equipment	Protective Clothing
Pollution Prevention/Response	Response Equipment	Sorbents

Appendix F. Example vessel spreadsheets

MARPOL Annex I Compliance Cost Analysis
Tanker 10600 DWT

Description	Lip Service Owner	Prudent Owner	Comments
Capital Costs			
OWS/OCM system	$ 22,500.00	$ 90,000.00	
OWS unit installation	$ 22,500.00	$ 90,000.00	Installation approx = system cost
OWS commissioning manufacturer's rep	$ 2,000.00	$ 4,000.00	Prudent includes operational training
Incinerator	$ 22,500.00	$ 22,500.00	Not required under Annex I
Incinerator installation	$ 22,500.00	$ 22,500.00	Not required under Annex I
Whitebox	$ -	$ 28,000.00	Not required under Annex I
Engineering costs	$ 2,000.00	$ 16,000.00	Prudent includes IBTS system
MARPOL Annex I certification / IOPP Supplement	$ 1,000.00	$ 1,000.00	
Sub-total capital costs	**$ 95,000.00**	**$ 274,000.00**	
Annualized equivalent	**$ 6,901.65**	**$ 19,905.80**	
Operating Costs			
Bilge water disposal	$ -	$ -	Assume none with OWS use
Shore disposal (after evaporation)	$ -	$ 4,569.13	Disposal costs vary widely by region
OWS consumable and maintenance costs	$ -	$ 851.67	Based on OWS system quality and amount of bilge water processed
OCM calibration and certification	$ 750.00	$ 750.00	Depends on unit, but ranges from $500-$2,000
Yearly tank and incinerator cleaning	$ -	$ 2,000.00	Includes disposal
Crew training seminar	$ -	$ 1,000.00	For C/E & Master
MARPOL Annex I certificate annual endorsement	$ 500.00	$ 500.00	Class or flag attendance; performed with other renewals
Sub-total yearly capital costs	**$ 1,250.00**	**$ 9,670.79**	
Totals			
Annual cost of compliance	$ 8,200.00	$ 29,600.00	
Annual cost of compliance including risk of PSC actions	$ 11,600.00	$ 31,600.00	See Risks tab for details
Annual cost of compliance including risk of PSC & DOJ actions	**$ 40,500.00**	**$ 31,600.00**	See Risks tab for details

MARPOL Annex I Compliance Cost Analysis
Potential PSC/DOJ Costs
Tanker 10600 DWT

Risk	Total cost	Comments	Risk*
Reported non-compliance	$ 20,000.00		10%
Detention in USA			
Loss of charter revenue	$ 19,080.00	Function of vessel type and deadweight tonnage	2.85%
Additional berthing costs (port berth)	$ 36,000.00	Lower of extra port berthing or anchorage + repositioning cost	2.85%
Flag attendance	$ 4,000.00		2.85%
Class attendance	$ 4,000.00		2.85%
Owner's surveyor attendance	$ 8,000.00		2.85%
Superintendent attendance	$ 2,800.00	Relocation and expenses	2.85%
Additional agent fees	$ 9,000.00	Unless re-negotiated	2.85%
External ISM audit	$ 5,000.00		2.85%
Legal/management logistics	$ 27,000.00		2.85%
Technician attendance	$ 5,000.00	Only applies with equipment failure detentions	1.43%
USCG removal of equipment	$ 2,000.00	E.g. computers	1.43%
Sub-total detention estimate	**$ 121,880.00**		
Weighted annual risk	**$ 3,375.88**	Assuming risk neutral shipowner	
Prosecution in USA			
Relocate vessel	$ 106,268.15	Moving vessel out of US trade (bunkers burned, loss of charter revenue)	1.04%
Replace crew on vessel	$ 4,000.00	$1,000/crew member	1.04%
Living costs of detained crew	$ 187,600.00	$100/crew member/day	1.04%
Civil attorneys (for company)	$ 375,200.00	Function of length of prosecution	1.04%
Criminal attorneys (for crew)	$ 375,200.00	Function of length of prosecution and # of crew	1.04%
Third party experts/consultants	$ 46,900.00	Function of length of prosecution	1.04%
Management time (in house)	$ 93,800.00	Function of length of prosecution	1.04%
Fine	$ 1,200,000.00	Average per vessel, 2007-17	1.04%
Community service payment	$ 340,000.00	Average per vessel, 2007-17	1.04%
ECP development	$ 20,000.00		0.73%
ECP increased audits (internal)	$ 5,000.00	1 audit/year	0.73%
ECP increased audits (external)	$ 18,000.00	1 audit/year	0.73%
ECP equipment upgrades	$ 28,000.00	E.g. whitebox installation	0.73%
Additional crew training	$ 5,000.00	5 yrs of annual training costs for C/E & Master (same as Prudent Owner)	1.04%
ECPs on other vessels in fleet	$ -	Assumed zero, but could be a significant cost (see Report)	
Reputational financial impact	$ -	Assumed zero, but could be a significant cost (see Report)	
Sub-total prosecution estimate	**$ 2,804,968.15**		
Weighted annual risk	**$ 28,866.49**	Assuming risk neutral shipowner	

* Among non-compliers, except for "reported non-compliance"

MARPOL Annex I Compliance Cost Analysis
Assumptions

These cells do not contain equations and can be easily altered

Description	Assumption	Comments	Sources
Ship Characteristics			
Ship size (deadweight tonnage)	10,600		
Main engine rating (kW)	7,000		
Ship type	Tanker		
Capital Cost Assumptions			
Discount rate	0.06	For time value of money	
Expected life of vessel (years)	30		M&O vessel database
Recommended oily waste tank capacity (days)	30		MARPOL Annex I, Reg 10.15.1
Operating Cost Assumptions			
Price of offloading sludge/bilge water (per MT)	$ 70.00	Varies widely by region (see report and Appendix B)	Industry input
Price of MGO (per MT)	$ 500.00	Feb 2017 approx. average worldwide	Bunkerworld
Price of HFO (per MT)	$ 300.00	Feb 2017 approx. average worldwide	Bunkerworld
Avg hrs steaming per day	20	Average over entire voyage (including port time)	Industry input
Bunkers burned daily (MT)	21	Assume 1/4 lb/HP/hr	Industry input
Bilge water daily generation (MT)	0.93	Based on IMO tank sizing recommendations	MEPC.1/Circ.642 - p.5
Sludge daily generation (MT)	0.21	Approx 1% of bunkers burned	MARPOL Annex I, interpret. to Reg 12
Residual waste from OWS to sludge	5%	5-15% of total bilge water volume (3-5% for best systems)	2011 EPA OWS paper, Attachment B
Sludge reduction through evaporation	20%	Based on water content of 20%, but varies	Industry input
Incinerator energy requirement (liters MGO per metric ton sludge)	250	Ranges from almost zero to 550 liters	Industry input
Evaporation energy requirement	0	Most vessels divert waste heat for evap.	Industry input
Density of MGO (MT/m3)	0.86		MGO Safety Data Sheet
PSC & DOJ Assumptions*			
Noncompliers (polluters)	8.5%	Based on detention data and MAX1 Survey (>500 anonymous survey responses)	2014-15 USCG data; MAX1 Studies survey
Number of vessels visiting US	9,076	Avg 2014-15	2015 & 2014 US PSC Annual Reports
Number of Annex I detentions per year	22	Avg 2014-15	2014-15 USCG data
% of vessels that get Annex I detentions	0.24%		Calculated
Likelihood of detention if non-compliant	2.85%	Assumes that only non-compliers get detained	Calculated
Number of Annex I DOJ prosecutions	8	Based on avg convictions per year from 2007-16	DOJ press releases
% of vessels that get Annex I prosecutions	0.09%		Calculated
Likelihood of DOJ prosecution if non-compliant	1.04%	Assumes that only non-compliers get prosecuted	Calculated
Conviction rate	100%	Rare innocent judgments or abandoned prosecutions in recent years	DOJ press releases
Percentage of prosec. resulting in ECP	70%		DOJ press releases
Length of detention (days)	9	Avg for PSC detentions related to Annex I violations	2014-15 USCG data
Length of company prosecution (months)	16	Average from 2007-17	DOJ press releases
Length of crew prosecution (months)	16	Assume similar to company prosecution	DOJ press releases
Number of crew members prosecuted	4	E.g. C/E, 2nd engineer, whistleblower, material witness	Industry input

* Data based on US costs and vessels with US ports of call

MARPOL Annex I Compliance Cost Analysis
Containership 66000 DWT

Description	Lip Service Owner	Prudent Owner	Comments
Capital Costs			
OWS/OCM system	$ 35,000.00	$ 140,000.00	
OWS unit installation	$ 35,000.00	$ 140,000.00	Installation approx = system cost
OWS commissioning manufacturer's rep	$ 2,000.00	$ 4,000.00	Prudent includes operational training
Incinerator	$ 35,000.00	$ 35,000.00	Not required under Annex I
Incinerator installation	$ 35,000.00	$ 35,000.00	Not required under Annex I
Whitebox	$ -	$ 28,000.00	Not required under Annex I
Engineering costs	$ 2,000.00	$ 16,000.00	Prudent includes IBTS system
MARPOL Annex I certification / IOPP Supplement	$ 1,000.00	$ 1,000.00	
Sub-total capital costs	**$ 145,000.00**	**$ 399,000.00**	
Annualized equivalent	**$ 10,534.09**	**$ 28,986.92**	
Operating Costs			
Bilge water disposal	$ -	$ -	Assume none with OWS use
Shore disposal (after evaporation)	$ -	$ 46,996.74	Disposal costs vary widely by region
OWS consumable and maintenance costs	$ -	$ 5,596.67	Based on OWS system quality and amount of bilge water processed
OCM calibration and certification	$ 750.00	$ 750.00	Depends on unit, but ranges from $500-$2,000
Yearly tank and incinerator cleaning	$ -	$ 2,000.00	Includes disposal
Crew training seminar	$ -	$ 1,000.00	For C/E & Master
MARPOL Annex I certificate annual endorsement	$ 500.00	$ 500.00	Class or flag attendance; performed with other renewals
Sub-total yearly capital costs	**$ 1,250.00**	**$ 56,843.41**	
Totals			
Annual cost of compliance	$ 11,800.00	$ 85,800.00	
Annual cost of compliance including risk of PSC actions	$ 18,900.00	$ 87,800.00	See Risks tab for details
Annual cost of compliance including risk of PSC & DOJ actions	**$ 56,900.00**	**$ 87,800.00**	See Risks tab for details

MARPOL Annex I Compliance Cost Analysis
Potential PSC/DOJ Costs
Containership 66000 DWT

Risk	Total cost	Comments	Risk*
Reported non-compliance	$ 20,000.00		10%
Detention in USA			
Loss of charter revenue	$ 148,500.00	Function of vessel type and deadweight tonnage	2.85%
Additional berthing costs (port berth)	$ 36,000.00	Lower of extra port berthing or anchorage + repositioning cost	2.85%
Flag attendance	$ 4,000.00		2.85%
Class attendance	$ 4,000.00		2.85%
Owner's surveyor attendance	$ 8,000.00		2.85%
Superintendent attendance	$ 2,800.00	Relocation and expenses	2.85%
Additional agent fees	$ 9,000.00	Unless re-negotiated	2.85%
External ISM audit	$ 5,000.00		2.85%
Legal/management logistics	$ 27,000.00		2.85%
Technician attendance	$ 5,000.00	Only applies with equipment failure detentions	1.43%
USCG removal of equipment	$ 2,000.00	E.g. computers	1.43%
Sub-total detention estimate	**$ 251,300.00**		
Weighted annual risk	**$ 7,066.60**	Assuming risk neutral shipowner	
Prosecution in USA			
Relocate vessel	$ 986,929.54	Moving vessel out of US trade (bunkers burned, loss of charter revenue)	1.04%
Replace crew on vessel	$ 4,000.00	$1,000/crew member	1.04%
Living costs of detained crew	$ 187,600.00	$100/crew member/day	1.04%
Civil attorneys (for company)	$ 375,200.00	Function of length of prosecution	1.04%
Criminal attorneys (for crew)	$ 375,200.00	Function of length of prosecution and # of crew	1.04%
Third party experts/consultants	$ 46,900.00	Function of length of prosecution	1.04%
Management time (in house)	$ 93,800.00	Function of length of prosecution	1.04%
Fine	$ 1,200,000.00	Average per vessel, 2007-17	1.04%
Community service payment	$ 340,000.00	Average per vessel, 2007-17	1.04%
ECP development	$ 20,000.00		0.73%
ECP increased audits (internal)	$ 5,000.00	1 audit/year	0.73%
ECP increased audits (external)	$ 18,000.00	1 audit/year	0.73%
ECP equipment upgrades	$ 28,000.00	E.g. whitebox installation	0.73%
Additional crew training	$ 5,000.00	5 yrs of annual training costs for C/E & Master (same as Prudent Owner)	1.04%
ECPs on other vessels in fleet	$ -	Assumed zero, but could be a significant cost (see Report)	
Reputational financial impact	$ -	Assumed zero, but could be a significant cost (see Report)	
Sub-total prosecution estimate	**$ 3,685,629.54**		
Weighted annual risk	**$ 37,998.91**	Assuming risk neutral shipowner	

* Among non-compliers, except for "reported non-compliance"

MARPOL Annex I Compliance Cost Analysis
Assumptions

These cells do not contain equations and can be easily altered

Description	Assumption	Comments	Sources
Ship Characteristics			
Ship size (deadweight tonnage)	66,000		
Main engine rating (kW)	72,000		
Ship type	Containership		
Capital Cost Assumptions			
Discount rate	0.06	For time value of money	
Expected life of vessel (years)	30		M&O vessel database
Recommended oily waste tank capacity (days)	30		MARPOL Annex I, Reg 10.15.1
Operating Cost Assumptions			
Price of offloading sludge/bilge water (per MT)	$ 70.00	Varies widely by region (see report and Appendix B)	Industry input
Price of MGO (per MT)	$ 500.00	Feb 2017 approx. average worldwide	Bunkerworld
Price of HFO (per MT)	$ 300.00	Feb 2017 approx. average worldwide	Bunkerworld
Avg hrs steaming per day	20	Average over entire voyage (including port time)	Industry input
Bunkers burned daily (MT)	219	Assume 1/4 lb/HP/hr	Industry input
Bilge water daily generation (MT)	6.13	Based on IMO tank sizing recommendations	MEPC.1/Circ.642 - p.5
Sludge daily generation (MT)	2.19	Approx 1% of bunkers burned	MARPOL Annex I, interpret. to Reg 12
Residual waste from OWS to sludge	5%	5-15% of total bilge water volume (3-5% for best systems)	2011 EPA OWS paper, Attachment B
Sludge reduction through evaporation	20%	Based on water content of 20%, but varies	Industry input
Incinerator energy requirement (liters MGO per metric ton sludge)	250	Ranges from almost zero to 550 liters	Industry input
Evaporation energy requirement	0	Most vessels divert waste heat for evap.	Industry input
Density of MGO (MT/m3)	0.86		MGO Safety Data Sheet
PSC & DOJ Assumptions*			
Noncompliers (polluters)	8.5%	Based on detention data and MAX1 Survey (>500 anonymous survey responses)	2014-15 USCG data; MAX1 Studies survey
Number of vessels visiting US	9,076	Avg 2014-15	2015 & 2014 US PSC Annual Reports
Number of Annex I detentions per year	22	Avg 2014-15	2014-15 USCG data
% of vessels that get Annex I detentions	0.24%		Calculated
Likelihood of detention if non-compliant	2.85%	Assumes that only non-compliers get detained	Calculated
Number of Annex I DOJ prosecutions	8	Based on avg convictions per year from 2007-16	DOJ press releases
% of vessels that get Annex I prosecutions	0.09%		Calculated
Likelihood of DOJ prosecution if non-compliant	1.04%	Assumes that only non-compliers get prosecuted	Calculated
Conviction rate	100%	Rare innocent judgments or abandoned prosecutions in recent years	DOJ press releases
Percentage of prosec. resulting in ECP	70%		DOJ press releases
Length of detention (days)	9	Avg for PSC detentions related to Annex I violations	2014-15 USCG data
Length of company prosecution (months)	16	Average from 2007-17	DOJ press releases
Length of crew prosecution (months)	16	Assume similar to company prosecution	DOJ press releases
Number of crew members prosecuted	4	E.g. C/E, 2nd engineer, whistleblower, material witness	Industry input

* Data based on US costs and vessels with US ports of call

MARPOL Annex I Compliance Cost Analysis
Bulk carrier 150000 DWT

Description	Lip Service Owner	Prudent Owner	Comments
Capital Costs			
OWS/OCM system	$ 30,000.00	$ 120,000.00	
OWS unit installation	$ 30,000.00	$ 120,000.00	Installation approx = system cost
OWS commissioning manufacturer's rep	$ 2,000.00	$ 4,000.00	Prudent includes operational training
Incinerator	$ 30,000.00	$ 30,000.00	Not required under Annex I
Incinerator installation	$ 30,000.00	$ 30,000.00	Not required under Annex I
Whitebox	$ -	$ 28,000.00	Not required under Annex I
Engineering costs	$ 2,000.00	$ 16,000.00	Prudent includes IBTS system
MARPOL Annex I certification / IOPP Supplement	$ 1,000.00	$ 1,000.00	
Sub-total capital costs	**$ 125,000.00**	**$ 349,000.00**	
Annualized equivalent	**$ 9,081.11**	**$ 25,354.47**	
Operating Costs			
Bilge water disposal	$ -	$ -	Assume none with OWS use
Shore disposal (after evaporation)	$ -	$ 11,749.18	Disposal costs vary widely by region
OWS consumable and maintenance costs	$ -	$ 2,190.00	Based on OWS system quality and amount of bilge water processed
OCM calibration and certification	$ 750.00	$ 750.00	Depends on unit, but ranges from $500-$2,000
Yearly tank and incinerator cleaning	$ -	$ 2,000.00	Includes disposal
Crew training seminar	$ -	$ 1,000.00	For C/E & Master
MARPOL Annex I certificate annual endorsement	$ 500.00	$ 500.00	Class or flag attendance; performed with other renewals
Sub-total yearly capital costs	**$ 1,250.00**	**$ 18,189.18**	
Totals			
Annual cost of compliance	$ 10,300.00	$ 43,500.00	
Annual cost of compliance including risk of PSC actions	$ 17,000.00	$ 45,500.00	See Risks tab for details
Annual cost of compliance including risk of PSC & DOJ actions	**$ 49,600.00**	**$ 45,500.00**	See Risks tab for details

MARPOL Annex I Compliance Cost Analysis
Potential PSC/DOJ Costs
Bulk carrier 150000 DWT

Risk	Total cost	Comments	Risk*
Reported non-compliance	$ 20,000.00		10%
Detention in USA			
Loss of charter revenue	$ 135,000.00	Function of vessel type and deadweight tonnage	2.85%
Additional berthing costs (port berth)	$ 36,000.00	Lower of extra port berthing or anchorage + repositioning cost	2.85%
Flag attendance	$ 4,000.00		2.85%
Class attendance	$ 4,000.00		2.85%
Owner's surveyor attendance	$ 8,000.00		2.85%
Superintendent attendance	$ 2,800.00	Relocation and expenses	2.85%
Additional agent fees	$ 9,000.00	Unless re-negotiated	2.85%
External ISM audit	$ 5,000.00		2.85%
Legal/management logistics	$ 27,000.00		2.85%
Technician attendance	$ 5,000.00	Only applies with equipment failure detentions	1.43%
USCG removal of equipment	$ 2,000.00	E.g. computers	1.43%
Sub-total detention estimate	**$ 237,800.00**		
Weighted annual risk	**$ 6,681.62**	Assuming risk neutral shipowner	
Prosecution in USA			
Relocate vessel	$ 464,232.38	Moving vessel out of US trade (bunkers burned, loss of charter revenue)	1.04%
Replace crew on vessel	$ 4,000.00	$1,000/crew member	1.04%
Living costs of detained crew	$ 187,600.00	$100/crew member/day	1.04%
Civil attorneys (for company)	$ 375,200.00	Function of length of prosecution	1.04%
Criminal attorneys (for crew)	$ 375,200.00	Function of length of prosecution and # of crew	1.04%
Third party experts/consultants	$ 46,900.00	Function of length of prosecution	1.04%
Management time (in house)	$ 93,800.00	Function of length of prosecution	1.04%
Fine	$ 1,200,000.00	Average per vessel, 2007-17	1.04%
Community service payment	$ 340,000.00	Average per vessel, 2007-17	1.04%
ECP development	$ 20,000.00		0.73%
ECP increased audits (internal)	$ 5,000.00	1 audit/year	0.73%
ECP increased audits (external)	$ 18,000.00	1 audit/year	0.73%
ECP equipment upgrades	$ 28,000.00	E.g. whitebox installation	0.73%
Additional crew training	$ 5,000.00	5 yrs of annual training costs for C/E & Master (same as Prudent Owner)	1.04%
ECPs on other vessels in fleet	$ -	Assumed zero, but could be a significant cost (see Report)	
Reputational financial impact	$ -	Assumed zero, but could be a significant cost (see Report)	
Sub-total prosecution estimate	**$ 3,162,932.38**		
Weighted annual risk	**$ 32,578.56**	Assuming risk neutral shipowner	

* Among non-compliers, except for "reported non-compliance"

MARPOL Annex I Compliance Cost Analysis
Assumptions

These cells do not contain equations and can be easily altered

Description	Assumption	Comments	Sources
Ship Characteristics			
Ship size (deadweight tonnage)	150,000		
Main engine rating (kW)	18,000		
Ship type	Bulk carrier		
Capital Cost Assumptions			
Discount rate	0.06	For time value of money	
Expected life of vessel (years)	30		M&O vessel database
Recommended oily waste tank capacity (days)	30		MARPOL Annex I, Reg 10.15.1
Operating Cost Assumptions			
Price of offloading sludge/bilge water (per MT)	$ 70.00	Varies widely by region (see report and Appendix B)	Industry input
Price of MGO (per MT)	$ 500.00	Feb 2017 approx. average worldwide	Bunkerworld
Price of HFO (per MT)	$ 300.00	Feb 2017 approx. average worldwide	Bunkerworld
Avg hrs steaming per day	20	Average over entire voyage (including port time)	Industry input
Bunkers burned daily (MT)	55	Assume 1/4 lb/HP/hr	Industry input
Bilge water daily generation (MT)	2.40	Based on IMO tank sizing recommendations	MEPC.1/Circ.642 - p.5
Sludge daily generation (MT)	0.55	Approx 1% of bunkers burned	MARPOL Annex I, interpret. to Reg 12
Residual waste from OWS to sludge	5%	5-15% of total bilge water volume (3-5% for best systems)	2011 EPA OWS paper, Attachment B
Sludge reduction through evaporation	20%	Based on water content of 20%, but varies	Industry input
Incinerator energy requirement (liters MGO per metric ton sludge)	250	Ranges from almost zero to 550 liters	Industry input
Evaporation energy requirement	0	Most vessels divert waste heat for evap.	Industry input
Density of MGO (MT/m3)	0.86		MGO Safety Data Sheet
PSC & DOJ Assumptions*			
Noncompliers (polluters)	8.5%	Based on detention data and MAX1 Survey (>500 anonymous survey responses)	2014-15 USCG data; MAX1 Studies survey
Number of vessels visiting US	9,076	Avg 2014-15	2015 & 2014 US PSC Annual Reports
Number of Annex I detentions per year	22	Avg 2014-15	2014-15 USCG data
% of vessels that get Annex I detentions	0.24%		Calculated
Likelihood of detention if non-compliant	2.85%	Assumes that only non-compliers get detained	Calculated
Number of Annex I DOJ prosecutions	8	Based on avg convictions per year from 2007-16	DOJ press releases
% of vessels that get Annex I prosecutions	0.09%		Calculated
Likelihood of DOJ prosecution if non-compliant	1.04%	Assumes that only non-compliers get prosecuted	Calculated
Conviction rate	100%	Rare innocent judgments or abandoned prosecutions in recent years	DOJ press releases
Percentage of prosec. resulting in ECP	70%		DOJ press releases
Length of detention (days)	9	Avg for PSC detentions related to Annex I violations	2014-15 USCG data
Length of company prosecution (months)	16	Average from 2007-17	DOJ press releases
Length of crew prosecution (months)	16	Assume similar to company prosecution	DOJ press releases
Number of crew members prosecuted	4	E.g. C/E, 2nd engineer, whistleblower, material witness	Industry input

* Data based on US costs and vessels with US ports of call

MARPOL Annex I Compliance Cost Analysis

Pax vessel

Description	Lip Service Owner	Prudent Owner	Comments
Capital Costs			
OWS/OCM system	$ 35,000.00	$ 140,000.00	
OWS unit installation	$ 35,000.00	$ 140,000.00	Installation approx = system cost
OWS commissioning manufacturer's rep	$ 2,000.00	$ 4,000.00	Prudent includes operational training
Incinerator	$ 35,000.00	$ 35,000.00	Not required under Annex I
Incinerator installation	$ 35,000.00	$ 35,000.00	Not required under Annex I
Whitebox	$ -	$ 28,000.00	Not required under Annex I
Engineering costs	$ 2,000.00	$ 16,000.00	Prudent includes IBTS system
MARPOL Annex I certification / IOPP Supplement	$ 1,000.00	$ 1,000.00	
Sub-total capital costs	**$ 145,000.00**	**$ 399,000.00**	
Annualized equivalent	**$ 9,381.57**	**$ 25,815.50**	
Operating Costs			
Bilge water disposal	$ -	$ -	Assume none with OWS use
Shore disposal (after evaporation)	$ -	$ 33,289.36	Disposal costs vary widely by region
OWS consumable and maintenance costs	$ -	$ 4,866.67	Based on OWS system quality and amount of bilge water processed
OCM calibration and certification	$ 750.00	$ 750.00	Depends on unit, but ranges from $500-$2,000
Yearly tank and incinerator cleaning	$ -	$ 2,000.00	Includes disposal
Crew training seminar	$ -	$ 1,000.00	For C/E & Master
MARPOL Annex I certificate annual endorsement	$ 500.00	$ 500.00	Class or flag attendance; performed with other renewals
Sub-total yearly capital costs	**$ 1,250.00**	**$ 42,406.02**	
Totals			
Annual cost of compliance	$ 10,600.00	$ 68,200.00	
Annual cost of compliance including risk of PSC actions	$ 13,400.00	$ 70,200.00	See Risks tab for details
Annual cost of compliance including risk of PSC & DOJ actions	**$ 41,200.00**	**$ 70,200.00**	See Risks tab for details

MARPOL Annex I Compliance Cost Analysis
Potential PSC/DOJ Costs
Pax vessel

Risk	Total cost	Comments	Risk*
Reported non-compliance	$ 20,000.00		10%
Detention in USA			
Loss of charter revenue	$ -	Function of vessel type and deadweight tonnage	2.85%
Additional berthing costs (port berth)	$ 36,000.00	Lower of extra port berthing or anchorage + repositioning cost	2.85%
Flag attendance	$ 4,000.00		2.85%
Class attendance	$ 4,000.00		2.85%
Owner's surveyor attendance	$ 8,000.00		2.85%
Superintendent attendance	$ 2,800.00	Relocation and expenses	2.85%
Additional agent fees	$ 9,000.00	Unless re-negotiated	2.85%
External ISM audit	$ 5,000.00		2.85%
Legal/management logistics	$ 27,000.00		2.85%
Technician attendance	$ 5,000.00	Only applies with equipment failure detentions	1.43%
USCG removal of equipment	$ 2,000.00	E.g. computers	1.43%
Sub-total detention estimate	**$ 102,800.00**		
Weighted annual risk	**$ 2,831.77**	Assuming risk neutral shipowner	
Prosecution in USA			
Relocate vessel	$ -	Moving vessel out of US trade (bunkers burned, loss of charter revenue)	1.04%
Replace crew on vessel	$ 4,000.00	$1,000/crew member	1.04%
Living costs of detained crew	$ 187,600.00	$100/crew member/day	1.04%
Civil attorneys (for company)	$ 375,200.00	Function of length of prosecution	1.04%
Criminal attorneys (for crew)	$ 375,200.00	Function of length of prosecution and # of crew	1.04%
Third party experts/consultants	$ 46,900.00	Function of length of prosecution	1.04%
Management time (in house)	$ 93,800.00	Function of length of prosecution	1.04%
Fine	$ 1,200,000.00	Average per vessel, 2007-17	1.04%
Community service payment	$ 340,000.00	Average per vessel, 2007-17	1.04%
ECP development	$ 20,000.00		0.73%
ECP increased audits (internal)	$ 5,000.00	1 audit/year	0.73%
ECP increased audits (external)	$ 18,000.00	1 audit/year	0.73%
ECP equipment upgrades	$ 28,000.00	E.g. whitebox installation	0.73%
Additional crew training	$ 5,000.00	5 yrs of annual training costs for C/E & Master (same as Prudent Owner)	1.04%
ECPs on other vessels in fleet	$ -	Assumed zero, but could be a significant cost (see Report)	
Reputational financial impact	$ -	Assumed zero, but could be a significant cost (see Report)	
Sub-total prosecution estimate	**$ 2,698,700.00**		
Weighted annual risk	**$ 27,764.50**	Assuming risk neutral shipowner	

* Among non-compliers, except for "reported non-compliance"

MARPOL Annex I Compliance Cost Analysis
Assumptions

These cells do not contain equations and can be easily altered

Description	Assumption	Comments	Sources
Ship Characteristics			
Ship size (deadweight tonnage)		3,000 pax	
Main engine rating (kW)	60,000		
Ship type	Pax vessel		
Capital Cost Assumptions			
Discount rate	0.06	For time value of money	
Expected life of vessel (years)	45		M&O vessel database
Recommended oily waste tank capacity (days)	30		MARPOL Annex I, Reg 10.15.1
Operating Cost Assumptions			
Price of offloading sludge/bilge water (per MT)	$ 70.00	Varies widely by region (see report and Appendix B)	Industry input
Price of MGO (per MT)	$ 500.00	Feb 2017 approx. average worldwide	Bunkerworld
Price of HFO (per MT)	$ 300.00	Feb 2017 approx. average worldwide	Bunkerworld
Avg hrs steaming per day	17	Average over entire voyage (including port time)	Industry input
Bunkers burned daily (MT)	155	Assume 1/4 lb/HP/hr	Industry input
Bilge water daily generation (MT)	5.33	Based on IMO tank sizing recommendations	MEPC.1/Circ.642 - p.5
Sludge daily generation (MT)	1.55	Approx 1% of bunkers burned	MARPOL Annex I, interpret. to Reg 12
Residual waste from OWS to sludge	5%	5-15% of total bilge water volume (3-5% for best systems)	2011 EPA OWS paper, Attachment B
Sludge reduction through evaporation	20%	Based on water content of 20%, but varies	Industry input
Incinerator energy requirement (liters MGO per metric ton sludge)	250	Ranges from almost zero to 550 liters	Industry input
Evaporation energy requirement	0	Most vessels divert waste heat for evap.	Industry input
Density of MGO (MT/m3)	0.86		MGO Safety Data Sheet
PSC & DOJ Assumptions*			
Noncompliers (polluters)	8.5%	Based on detention data and MAX1 Survey (>500 anonymous survey responses)	2014-15 USCG data; MAX1 Studies survey
Number of vessels visiting US	9,076	Avg 2014-15	2015 & 2014 US PSC Annual Reports
Number of Annex I detentions per year	22	Avg 2014-15	2014-15 USCG data
% of vessels that get Annex I detentions	0.24%		Calculated
Likelihood of detention if non-compliant	2.85%	Assumes that only non-compliers get detained	Calculated
Number of Annex I DOJ prosecutions	8	Based on avg convictions per year from 2007-16	DOJ press releases
% of vessels that get Annex I prosecutions	0.09%		Calculated
Likelihood of DOJ prosecution if non-compliant	1.04%	Assumes that only non-compliers get prosecuted	Calculated
Conviction rate	100%	Rare innocent judgments or abandoned prosecutions in recent years	DOJ press releases
Percentage of prosec. resulting in ECP	70%		DOJ press releases
Length of detention (days)	9	Avg for PSC detentions related to Annex I violations	2014-15 USCG data
Length of company prosecution (months)	16	Average from 2007-17	DOJ press releases
Length of crew prosecution (months)	16	Assume similar to company prosecution	DOJ press releases
Number of crew members prosecuted	4	E.g. C/E, 2nd engineer, whistleblower, material witness	Industry input

* Data based on US costs and vessels with US ports of call

MARPOL Annex I Compliance Cost Analysis
Tanker 280000 DWT

Description	Lip Service Owner	Prudent Owner	Comments
Capital Costs			
OWS/OCM system	$ 35,000.00	$ 140,000.00	
OWS unit installation	$ 35,000.00	$ 140,000.00	Installation approx = system cost
OWS commissioning manufacturer's rep	$ 2,000.00	$ 4,000.00	Prudent includes operational training
Incinerator	$ 35,000.00	$ 35,000.00	Not required under Annex I
Incinerator installation	$ 35,000.00	$ 35,000.00	Not required under Annex I
Whitebox	$ -	$ 28,000.00	Not required under Annex I
Engineering costs	$ 2,000.00	$ 16,000.00	Prudent includes IBTS system
MARPOL Annex I certification / IOPP Supplement	$ 1,000.00	$ 1,000.00	
Sub-total capital costs	**$ 145,000.00**	**$ 399,000.00**	
Annualized equivalent	**$ 10,534.09**	**$ 28,986.92**	
Operating Costs			
Bilge water disposal	$ -	$ -	Assume none with OWS use
Shore disposal (after evaporation)	$ -	$ 29,372.96	Disposal costs vary widely by region
OWS consumable and maintenance costs	$ -	$ 3,954.17	Based on OWS system quality and amount of bilge water processed
OCM calibration and certification	$ 750.00	$ 750.00	Depends on unit, but ranges from $500-$2,000
Yearly tank and incinerator cleaning	$ -	$ 2,000.00	Includes disposal
Crew training seminar	$ -	$ 1,000.00	For C/E & Master
MARPOL Annex I certificate annual endorsement	$ 500.00	$ 500.00	Class or flag attendance; performed with other renewals
Sub-total yearly capital costs	**$ 1,250.00**	**$ 37,577.13**	
Totals			
Annual cost of compliance	$ 11,800.00	$ 66,600.00	
Annual cost of compliance including risk of PSC actions	$ 29,000.00	$ 68,600.00	See Risks tab for details
Annual cost of compliance including risk of PSC & DOJ actions	**$ 72,600.00**	**$ 68,600.00**	See Risks tab for details

MARPOL Annex I Compliance Cost Analysis
Potential PSC/DOJ Costs
Tanker 280000 DWT

Risk	Total cost	Comments	Risk*
Reported non-compliance	$ 20,000.00		10%
Detention in USA			
Loss of charter revenue	$ 504,000.00	Function of vessel type and deadweight tonnage	2.85%
Additional berthing costs (port berth)	$ 36,000.00	Lower of extra port berthing or anchorage + repositioning cost	2.85%
Flag attendance	$ 4,000.00		2.85%
Class attendance	$ 4,000.00		2.85%
Owner's surveyor attendance	$ 8,000.00		2.85%
Superintendent attendance	$ 2,800.00	Relocation and expenses	2.85%
Additional agent fees	$ 9,000.00	Unless re-negotiated	2.85%
External ISM audit	$ 5,000.00		2.85%
Legal/management logistics	$ 27,000.00		2.85%
Technician attendance	$ 5,000.00	Only applies with equipment failure detentions	1.43%
USCG removal of equipment	$ 2,000.00	E.g. computers	1.43%
Sub-total detention estimate	**$ 606,800.00**		
Weighted annual risk	**$ 17,204.52**	Assuming risk neutral shipowner	
Prosecution in USA			
Relocate vessel	$ 1,530,580.96	Moving vessel out of US trade (bunkers burned, loss of charter revenue)	1.04%
Replace crew on vessel	$ 4,000.00	$1,000/crew member	1.04%
Living costs of detained crew	$ 187,600.00	$100/crew member/day	1.04%
Civil attorneys (for company)	$ 375,200.00	Function of length of prosecution	1.04%
Criminal attorneys (for crew)	$ 375,200.00	Function of length of prosecution and # of crew	1.04%
Third party experts/consultants	$ 46,900.00	Function of length of prosecution	1.04%
Management time (in house)	$ 93,800.00	Function of length of prosecution	1.04%
Fine	$ 1,200,000.00	Average per vessel, 2007-17	1.04%
Community service payment	$ 340,000.00	Average per vessel, 2007-17	1.04%
ECP development	$ 20,000.00		0.73%
ECP increased audits (internal)	$ 5,000.00	1 audit/year	0.73%
ECP increased audits (external)	$ 18,000.00	1 audit/year	0.73%
ECP equipment upgrades	$ 28,000.00	E.g. whitebox installation	0.73%
Additional crew training	$ 5,000.00	5 yrs of annual training costs for C/E & Master (same as Prudent Owner)	1.04%
ECPs on other vessels in fleet	$ -	Assumed zero, but could be a significant cost (see Report)	
Reputational financial impact	$ -	Assumed zero, but could be a significant cost (see Report)	
Sub-total prosecution estimate	**$ 4,229,280.96**		
Weighted annual risk	**$ 43,636.54**	Assuming risk neutral shipowner	

* Among non-compliers, except for "reported non-compliance"

MARPOL Annex I Compliance Cost Analysis
Assumptions

These cells do not contain equations and can be easily altered

Description	Assumption	Comments	Sources
Ship Characteristics			
Ship size (deadweight tonnage)	280,000		
Main engine rating (kW)	45,000		
Ship type	Tanker		
Capital Cost Assumptions			
Discount rate	0.06	For time value of money	
Expected life of vessel (years)	30		M&O vessel database
Recommended oily waste tank capacity (days)	30		MARPOL Annex I, Reg 10.15.1
Operating Cost Assumptions			
Price of offloading sludge/bilge water (per MT)	$ 70.00	Varies widely by region (see report and Appendix B)	Industry input
Price of MGO (per MT)	$ 500.00	Feb 2017 approx. average worldwide	Bunkerworld
Price of HFO (per MT)	$ 300.00	Feb 2017 approx. average worldwide	Bunkerworld
Avg hrs steaming per day	20	Average over entire voyage (including port time)	Industry input
Bunkers burned daily (MT)	137	Assume 1/4 lb/HP/hr	Industry input
Bilge water daily generation (MT)	4.33	Based on IMO tank sizing recommendations	MEPC.1/Circ.642 - p.5
Sludge daily generation (MT)	1.37	Approx 1% of bunkers burned	MARPOL Annex I, interpret. to Reg 12
Residual waste from OWS to sludge	5%	5-15% of total bilge water volume (3-5% for best systems)	2011 EPA OWS paper, Attachment B
Sludge reduction through evaporation	20%	Based on water content of 20%, but varies	Industry input
Incinerator energy requirement (liters MGO per metric ton sludge)	250	Ranges from almost zero to 550 liters	Industry input
Evaporation energy requirement	0	Most vessels divert waste heat for evap.	Industry input
Density of MGO (MT/m3)	0.86		MGO Safety Data Sheet
PSC & DOJ Assumptions*			
Noncompliers (polluters)	8.5%	Based on detention data and MAX1 Survey (>500 anonymous survey responses)	2014-15 USCG data; MAX1 Studies survey
Number of vessels visiting US	9,076	Avg 2014-15	2015 & 2014 US PSC Annual Reports
Number of Annex I detentions per year	22	Avg 2014-15	2014-15 USCG data
% of vessels that get Annex I detentions	0.24%		Calculated
Likelihood of detention if non-compliant	2.85%	Assumes that only non-compliers get detained	Calculated
Number of Annex I DOJ prosecutions	8	Based on avg convictions per year from 2007-16	DOJ press releases
% of vessels that get Annex I prosecutions	0.09%		Calculated
Likelihood of DOJ prosecution if non-compliant	1.04%	Assumes that only non-compliers get prosecuted	Calculated
Conviction rate	100%	Rare innocent judgments or abandoned prosecutions in recent years	DOJ press releases
Percentage of prosec. resulting in ECP	70%		DOJ press releases
Length of detention (days)	9	Avg for PSC detentions related to Annex I violations	2014-15 USCG data
Length of company prosecution (months)	16	Average from 2007-17	DOJ press releases
Length of crew prosecution (months)	16	Assume similar to company prosecution	DOJ press releases
Number of crew members prosecuted	4	E.g. C/E, 2nd engineer, whistleblower, material witness	Industry input

* Data based on US costs and vessels with US ports of call