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ROYAL HASKONING

HASKONING NEDERLAND BV
ENVIRONMENTAL MANAGEMENT

Entrada 301	
Postbus 94241	
Amsterdam 1090 GE	
The Netherlands	
+31 (0)20 569 77 00	Telephone
	Fax
info@amsterdam.royalhaskoning.com	E-mail
www.royalhaskoning.com	Internet
Arnhem 09122561	CoC

Global Market Analysis of Ballast Water Treatment Technology

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Drafted by	Mr. Frans Tjallingii, Mr. Herbert Schilperoord
Checked by	Mr. H. van Niekerk
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SUMMARY

This report provides a global analysis of the market for a ballast water treatment technology industry. Specifically, the report describes the probable market for ballast treatment systems in light of forthcoming national and international ballast water management requirements. The report also outlines the technical characteristics of selected vessels and provides information on situations in which ballast water treatment will likely be implemented. The characteristics of the vessels thought most likely to adopt on board ballast water treatment first are also identified.

Three ballast treatment market phases were identified: The first comes before the signing of an IMO (International Maritime Organisation) convention in 2003, the second is between signing and its ratification, which we assumed to be five years later (in 2008), and the third comes after the “entry into force” of the convention.

The potential market for ballast water treatment comprises new vessels with built-in treatment facilities, and existing vessels in which treatment facilities may be retrofitted. Prior to 2003 it is assumed that some vessels will adopt ballast water treatment (though no formal international regime will be present) in response to the current mandatory requirements (e.g., Great Lakes and California), or in an effort to be good corporate citizens by helping the technology development process. Between 2003 and 2008 the market will grow to include those ship owners that anticipate the upcoming convention, and the growing number of ship owners whose ships must perform ballast water management due to unilateral legislation. After 2008 all internationally trading vessels that use seawater as ships ballast are likely to fall under the IMO convention.

It is probable that ballast water exchange (BWE) will remain an option open to ship owners for some time to come. Thus they will be able to choose between on board ballast water treatment (BWT) and ballast water exchange. The outcome of this choice will be primarily dependent upon the availability of techniques which are better or more economical than ballast water exchange.

BWT still faces technical challenges before it can provide a sound alternative for BWE. The most important difficulties are those related to retrofitting equipment into existing ships, especially where the flow rates are high and available space for equipment is limited. Sea borne environments, which are paramount to corrosion, vibrations and other problems must be dealt with also.

The study concludes that there are large potential returns on investment in ballast water treatment solutions to the shipping industry. After the IMO treaty ratification these returns could amount to over 1 billion USD per year (*mid term*). The diversity of ship types, sizes and trades will result in a market which has room for many different techniques.

There are many technical challenges to be overcome and many policy uncertainties. But there is no doubt that a strong demand for an environmentally sound and effective ballast water treatment technology will emerge in the not-too-distant future. The best way to assure that the introduction of a treatment technique will be successful is through investment in research and development combined with a sound marketing strategy.

CONTENTS

1 INTRODUCTION

1.1 Reference

The use of seawater as ballast for the stability and trim of vessels poses the risk of the introduction of aquatic organisms and pathogens in alien marine environments. At present, minimisation of this risk is sought through the on-board treatment of ballast water (BWT), as an alternative for ballast water exchange. A number of potential systems and technologies for BWT are now beginning to emerge in response to this need.

The BWT industry start-up has been slow to date for a number of reasons. Firstly, a range of different systems and technologies is needed to address the range of ship and voyage types; a single “silver bullet” will not satisfy the maritime industry’s needs. Secondly, water treatment companies which have expertise in potential treatment technologies have not been well acquainted with the shipping industry as a client, and are not familiar with the ballast water problem. Furthermore, the development and introduction of new systems and technologies can be a lengthy and expensive affair with many uncertainties. On the other hand, the opportunity is a virtually untapped market: the global shipping industry with over 30,000 vessels engaged in international trade.

This ROYAL HASKONING report has been contracted by the Northeast- Midwest Institute (order no. 040240 ROYAL HASKONING) to describe the possible market for BWT in an effort to stimulate investment in Research and Development (R&D) of BWT systems. This study is performed in co-operation with the International Chamber of Shipping and INTERTANKO.

1.2 Background

The introduction of alien organisms to an environment has often been traced back to the translocation of ballast water and sediments. This process can have environmental, economic and health effects, which may range from degraded or clogged waterways (e.g. caused by growth of zebra mussels in the Great Lakes), fish deaths (comb jellyfish) to human illness or even deaths (e.g. due to toxic dinoflagellates).

These threats are increasingly recognised by governments and international maritime, environmental and public health bodies. Unilateral legislation has therefore been implemented in different countries, and is being developed in many others (see ICS/INTERTANKO (1998)). These regulations require vessel operators to manage their ballast water to prevent species transfers. Most of these regulations follow the principles set out by the International Maritime Organisation (IMO) in 1997 (resolution A. 868(20)). Ballast Water Exchange (BWE) is still the major option available to ship owners to comply with these regulations.

Ballast water exchange (BWE) cannot be utilised in near shore voyages and can be dangerous to the ship under certain circumstances due to excessive hull stresses and strains. The efficacy of BWE is still largely unknown. These issues have led to an interest in ballast water treatment technology as an alternative option for ballast water management.

The shipping industry and international maritime organisations have acknowledged the problem of translocation of ‘foreign’ aquatic species in ballast water and the need to reduce these translocations. They are also increasingly aware of forthcoming regulations and are interested in developing their options. Within the Ballast Water Working Group of the Marine Environmental Protection Committee (MEPC), a group has been assigned under the lead of the United States to develop a technical performance standard for BWT. The members of MEPC aim to sign a convention in the year 2003**.**

BWT: a market seeking caterers

A biological effectiveness standard is being developed (IMO BWWG) to provide clear guidance to producers of ballast water treatment systems and technologies. This standard is expected to be incorporated into the international convention, and will provide a basis for certification of treatment equipment by authorised bodies. Certification of systems and technologies is expected to facilitate the willingness of ship owners to procure and use BWT equipment.

On many occasions representatives of ship owners have expressed the need for a range of certified technologies and equipment (a "toolbox") that they can choose from, in order to comply with international and local regulatory regimes. The first technical options for ballast water treatment are currently being marketed, but still represent only a limited set of options.

How then can this toolbox be developed further? The answer lies in a combination of factors, particularly financing as well as more insight to the needs, wishes, requirements and constraints in the market so that suppliers of treatment can invest in conceptualising, designing, developing, building, testing and marketing technologies and equipment.

A lack of familiarity with the problem of ballast water and a lack of knowledge of the shipping sector currently inhibit investment into treatment systems for ships' ballast water. A technical constraint is the 'translation' of existing and field tested 'on-shore technology and equipment' to the 'on-board environment' with its different characteristics.

BWT: wishes of the shipping industry

In a market analysis the first item of consideration is what the customer wants. The incentives for ship owners to buy an installation arise from ongoing legislation, initiatives and the increasing knowledge of the problems associated with ballast water. If a ship owner buys a technique, what will he be looking for? Here we have tried to outline these requirements, based on the speech by Alec Bilney (ICS) at the first International Ballast Water Treatment Symposium (IMO London, March 2001).

- Any technique must not hamper free global trade, and must therefore be accepted by all port authorities through certification according to international standards;
- A ship owner must be able to choose from a range of techniques, to suit his ship and the ships operation;
- Any technique must meet a set of basic criteria, which are already identified in a number of IMO documents, as defined in the reports of the Ballast Water Working Group at MEPC 45 and the recent Global Ballast Water Workshop. Any technique must be:
- safe for ship and crew;
- environmentally acceptable;
- practicable (can be implemented and operated within the constraints of ship design and operations);
- economical (cost-effectiveness);
- biologically effective (the technology should do what it is meant to).

Project Goals
This project provides the water treatment industry with an insight in the market for BWT and an idea of the gains that can be made from sales.
More importantly, during the project the market was identified, and its constraints and possibilities, both technically and otherwise are shown.

The goal of the project is in the first place creating a better understanding in the market for BWT, and in second place stimulating the water treatment industry with an analysis of the gains that can be made with successful R&D.

Reading Directions
The approach of the study is described in chapter 2. Chapter 3 contains the opinions of consulted experts regarding the market for BWT. Chapter 4 gives background information on the fitting of BWT on board vessels: the technical constraints and possibilities. Chapter 5 presents the principal characteristics of the world fleet, which are used in chapter 6 for calculating potential turnover in the market for BWT. Chapter 7 concludes the report by summarising the results and evaluating the findings and methodology.

2 APPROACH

2.1 General Approach

The study uses a three-step approach to describe the market for BWT. This chapter first describes the approach in general, and then explains the different activities that were performed for the study.

The starting point of the study was that potentially, the world fleet is the market, but that due to different reasons not all vessels will require or wish BWT (see figure 1: potential market). The analysis steps were identified through questionnaires, which were presented to representatives of ship owners and other experts in the field (expert round 1).

A technical analysis of different vessels was performed to determine the technical possibilities on different vessels. These aspects combined were used to determine the "qualified available market" (step 2).

The qualified available market was then used for an analysis (again based on an expert group survey (expert round 2)) to predict future market behaviour. The end result is an estimated time frame of the number of vessels that may adopt BWT (step 3). Together with the qualifications and assumptions, this estimate provides an idea of the market revenue that may be expected during the next decades.

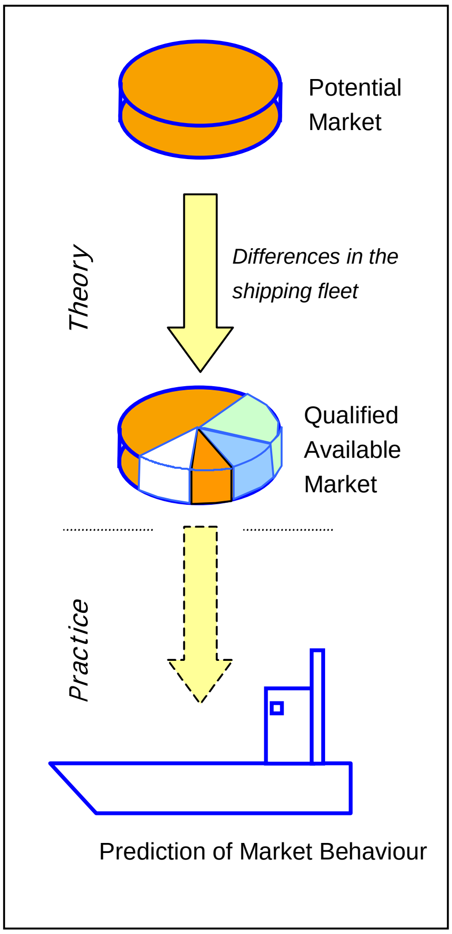


Figure 1: *Approach to BWT market analysis*

2.2 Activities

Three sets of activities were performed during the study: a ship owners survey, an expert group survey and a database analysis. The three are described below.

2.2.1 Ship Owners Survey

The first activity involvee interviews with ship owners in the Netherlands. In co-operation with the design departments of ship owners base-line criteria will be developed for new and existing vessels. The vessel types to be included in the analysis are in any case:

- general cargo, deep sea;
- general cargo, short sea;
- tankers (chemical);
- container ships;
- passenger vessels;

For each of these vessel types the following aspects will be described:

The criteria named above determine the installations that can be used on different vessels. Analysing the build up of the world fleet based on these criteria will provide an overview of the possible market sectors for different techniques. If, for example, a product is dependent on waste heat, it will not be applicable in that fleet sector which does not produce sufficient quantities.

2.2.2 Expert Group Survey

The expert rounds consisted of questionnaires with part open questions and part statements to which the respondent could indicate whether he agreed or disagreed, with response. The completed questionnaires are enclosed in appendix 1.

The aim of expert round 1 was to gain a first impression of the possibilities to formulate queries on the world fleet. It also included questions on the criteria that would determine whether ship owners would adopt BWT, and in what order.

Expert round 2 was more comprehensive and less open than round 1. It consisted mostly of statements concerning the probable behaviour of different ship owners based on their vessel type, vessel age, flag, awareness and other aspects. A last important aspect was that respondents were asked to indicate the expected trends in the world fleet.

2.2.3 Database Analysis Lloyds Register

Lloyds Register of Ships is the worlds leading vessel database, being of over 100 000 vessels. In this study the Lloyds Register was used to derive numbers of vessels in certain categories. The queries used were based on the expert rounds as described above.

The queries have provided data on vessel type, size (DWT), flag and age distributions. These data were then translated to market sectors for different techniques. In addition, the derived figures were used to predict a phasing in distribution for BWT in a set of steps.

3 MARKET CHARACTERISTICS

The statements below were based on the response from the 2 expert rounds. The consulted experts often had divergent opinions, and often no clear-cut conclusions could be drawn to predict future adoption patterns. The questionnaires did however provide lot of information as most points of view were well documented. Discerning views often provided a lot of information, which qualifies the market in the world fleet. Below is a summary of the results. The compilation reports of the expert rounds are included in appendix 1 and 2.

3.1 Towards regulations

The major driving force for adopting BWT is the development of regulations on ballast water management. At present some 14 countries (see eg. ICS/INTERTANKO 1998, ROYAL HASKONING 2001) have regulations in place which demand some form of ballast water management. These current domestic and port of call legislation are already a driving force for ship owners to consider alternatives to BWE.

The respondents identified the lack of current performance standards as the major reason that ship owners are hesitant to invest more in BWT. It is currently expected that a convention will be signed in 2003. This will mean that a standard will then be known, but the convention will probably contain a phasing in schedule that is based on size, type and age of the vessel.

The IMO has in past adopted many different models for phasing in of regulations. None of the respondents felt confident to suggest a schedule for phasing in.

With respect to requirements on existing ships, the convention may discern between the countries, which presently have regulations, or regard ballast water as an issue with some priority. These countries are most probably amongst others, Australia, USA, EU, New Zealand, Canada, Equador, Chile, Argentina, Brazil and possibly GloBallast pilot countries[1].

In future, a preference by port states for BWT over BWE could lead to some nations restricting ballast management to BWT. Ship owners that build new vessels may wish to install BWT in advance of this development so that they will be able to readily visit those countries. Concern for flexibility of movement and the possibility for resale of the vessel may then enhance the adoption of BWT.

3.2 Criteria for BWT

From the ship owner’s point of view the most important criterion for BWT is that it meets the regulations: it must meet the coming IMO standard, and must be accepted by port states. As described in the paragraph on regulations, the lack of a standard may be the main factor inhibiting many ship owners from adoption of BWT in advance of international requirements. The good news is that a standard is likely within the next two years.

Once BWT can be type-approved against a standard as acceptable to the relevant authorities, secondary criteria become important. One question is whether the ship owner is to choose BWT over BWE. According to the ROYAL HASKONING survey, the

[1] www.Globallast.org

operating cost of the installation (i.e. the cost of operating the system over the lifetime of the installation) is the most important criterion. Initial investment cost and construction details are secondary.
Other criteria regarding the acceptance of BWT are:

- Reliability, user friendliness and other technical aspects were termed less important than costs, although not in agreement by all;
- Most other named criteria are either linked to costs or to acceptability (eg environmentally soundness);
- The system should be based on a known technology, and be backed by a known engineering firm;
- The introduction of BWT can be considered a success when it is specified by a ship owner in a new building contract, and when it has been approved by the IMO or identified by a port state as meeting treatment requirements for a certain class of ships;
- High capacity, compliance with regulations and standards, low investment and low maintenance cost, Effective and volume friendly and acceptance by legislation;
- Shipboard performance and reliability at pilot scale would be the first predictive indication, then biological performance data, shipboard tests, cost estimates, and the availability to a variety of vessels.

3.3 Adoption of BWT

BWT is seen as an alternative to BWE with advantages related to the safety of the vessel (no bending moments). Improved methods for BWE are also an option for the ship owner. At present BWT is not a foregone conclusion for all ships mostly because of a lack of high-performance prospects for ships, which ballast at extremely high-flow rates. Thus, while most classes of ships will elect to install BWT if the overall cost is less or similar than BWE, BWE remains an option.

The major reason that BWT is not adopted at present is the lack of standards. A small market has already come into existence.

Vessels may consider installing BWT even in the absence of standards to remain attractive to prospective charterers. When building a vessel, the owner can take into account that during the lifetime of the vessel, the ship may trade in different areas. Some charter parties may in future demand BWT to be on board the vessel as part of the standard equipment.
As using BWE instead of BWT increases bunker consumption (up to 15%), charters may demand BWT, since bunkers are normally paid by the charters.

In anticipation of the phase-in schedule to be adopted in 2003, new vessels will probably install BWT, or design tanks and pumps for safer and more effective BWE. The market for BWT will consist of ship owners that have sufficient awareness of the coming regulations to take these into account when building a new ship in the near future.

Increased awareness is present with ship owners that sail to ports requiring BW management or have access to information on ballast water in an other way.

After standards are agreed on, ship owners with needed awareness will adopt BWT (also before the convention is ratified and comes into effect). Adoption of BWT on ships before the convention is ratified depends on the progressiveness of the ship owner. Large ship owners may wish to run pilot tests to be able to determine the effects of ballast water regulations for their entire fleet. Ship owners from countries with BW legislation in place and industrialised countries (Europe, Japan etc) can be considered to have the needed awareness to cope with early adoption. This does not necessarily correspond with the flag, which the respective vessel flies.

In the pilot countries for the GloBallast project, the different national shipowners' associations are usually involved. The ship owners of these nationalities may thus gain added awareness, but it is too early in the project to conclude whether this will result in pro-active adoption of BWT. Developing countries in general will have no extra money for experimental BWT.

Green image building may cause some ship owners to adopt BWT before the convention comes into force. This refers to (larger) ship owners certified under ISO 14000 or with high environmental profiles. The cruise industry, with a very public function is sensitive to its environmental profile.

3.4 Retrofitting

The likeliness of retrofitting (building in BWT in existing vessels) depends on the developments in BWT. If BWT options are adequately small, cheap and powerful (flow rates) and the individual vessel has the right circumstances (space, energy, piping etc) on board retrofit may occur. Even then the choice will again be made between systems for BWE and the available BWT.

The economic lifetime of the vessel may be a criterion taken into account when deciding on retrofit. Retrofit could be considered for vessels up to 5 or 10 years of age, however this is very dependent on the type size and trade of the vessel.

Again, when discussing regulations, some countries may unilaterally decide to demand BWT instead of leaving BWE open as an option. Vessels trading on these countries will retrofit BWT. For cruise ships, that operate in sensitive areas (Alaska, Antarctica etc.) BWT retrofitting may also be more likely.

Concluding, retrofit will only take place if:
- the cost is low;
- and operational costs are markedly lower than BWE;
- and if the vessel has an assured trading pattern that will insist on something being done.

Retrofitting becomes increasingly difficult (but not out of the question) as the age of the ship increases.

3.5 Vessel types and trades

The respondents to the questionnaire were asked to name the vessel types that would be first to adopt BWT. Combining all reactions the following vessel types were indicated:

- Cruise liners. Sensitive areas such as Alaska, Antarctica and the Caribbean, and the shifting nature of the trade will require this high profile trade to be the first to adopt BWT. This will be necessary for new and existing vessels. The cruise industry is not separate, as it falls under the same legislation as other ships, but seems to be more progressive due to their different market in which a green image is rewarded and not only the price per tonkilometer counts. The cruise ship industry may act as a testing ground for up-scaleable technologies. Because of low flow rates, BWT is easier to install on these vessels.

- Bulk Carriers. These vessels are not well adapted to BWE, and are therefore most likely to adopt BWT once an acceptable option is proposed (as opposed to BWE). For Bulk Carriers retrofit is not very likely due to the costs involved. Australia has a lot of bulk trade, and because of its ballast water management requirements informs ship owners on the status of BWT.
- Tankers can perform BWE with more ease, BWT will therefore have strong advantages to be adopted. Tankers need installations with high flow rates.
- Container Vessels (including RoRo vessels and Ferries), use ballast water for manoeuvring in the harbour. Retrofit will depend on port state requirements (whether demanded in addition to BWE). New vessels will be required to perform BWT or BWE. For these vessels high flow rates are needed.
- General Cargo, Reefers, and other dedicated trade vessels. As transport is becoming more containerised, it is expected that in the next decades these vessel types will decrease. In any case these vessel types will probably be last. General cargo' is a diverse ship type covering different trades. General Cargo shipping will remain significant in future as it fulfils a necessary role. It is likely however that based on tonnage the market share of this segment may decrease and may eventually result in lower numbers of vessels in future. Due to the size of many companies sailing general cargo ships, these operators will probably not install BWT before the Convention is in effect. The average age of general cargo vessels is approximately 18 years, in relation to the average scrapping age of 25 years: there may be little economic merit to retrofit these vessels.
- Miscellaneous ship types (some 30% of the world fleet (in numbers): Off shore rigs, LPG/LNG carriers, submersible heavy lift vessels etc. might need separate attention. Fishing boats are not as important as they take up water in the harbour and discharge the water on the fishing grounds mostly not far away. Some vessels (eg. heavy transport vessels) may have severe problems with some of the regulations as they sometimes have no pumping installations or have other major technical differences to the "standard vessel" design. On the other hand, many of these categories may not be relevant in respect to ballast water treatment due to very local operations, or the absence of ballast water.

3.6 Parcel Trade versus Bulk Trade /Coastal versus Intercontinental trades

Short voyages (coastal trade) may be seen as a reason to exempt vessels from performing ballast water treatment due to the fact that they operate in one bioregion. It is however possible that in some instances (eg. toxic blooms) regional trading patterns may be responsible for spreading the alien organism faster. Not installing BWT limits the flexibility of the vessel and the possibilities for resale. Ships on intercontinental voyages will probably need to perform BWE/BWT independent of size and type.

Parcel trade means that cargo is subdivided in parts, and that the vessel can load and unload part of its cargo in different ports. On average parcel vessels transport less ballast water because they are more flexible in taking up cargo. Although parcel trade requires short, regional voyages, which are rarely under full ballast, ship owners may choose to install BWT for added flexibility of trade and to be able to sell the vessel at a better price later on.

Larger vessels (bulk trades) however carry a higher percentage of ballast in relation to transported cargo. Larger bulk vessels often operate in Loaded Out- Ballast Back (LOBB). The link to risk assessment is however disputed.

3.7 Fleet developments

The expert group members were asked to indicate their expectations on the developments in the world market for the next ten years. The indicated percentages are qualified in the table below (table 1).

Table 1: fleet forecasts by the expert group per vessel type

Main category	Current number	Forecast:
Crude tankers	1,800	Slight increase
Product tankers	1,200	Increase
Liquefied gas tankers	1,100	Increase
Chemical tankers	1,200	Slight increase
Bulk carriers	5,800	Decrease
Container ships	2,600	Slight increase
General cargo	17,500	Decrease
Refrigerated cargo	1,400	No growth or slight decrease
Ro-Ro ships	4,000	Increase
Cruise ships	350	Increase
Passenger ships	2,400	No growth

It is concluded that most vessel types will show an (slight) increase in the next decade. Decreases are predicted for bulk carriers, general cargo vessels and refrigerated cargo vessels. The general trend is that cargo is becoming more and more containerised. Containerised transport is more flexible: any vessel with container capacity can transport a wide variety of containerised cargo. Bulk vessels are often dedicated to certain (groups of) products and will sail in ballast the return voyage. Refrigerated cargo is also increasingly being transported in reefer containers.

For the general cargo fleet, the opinion is that a sufficient market exists to keep this vessel category significant in the future (Many general cargo vessels can also serve as container feeders).

3.8 Sediments

During the survey for the Royal Association of Netherlands' Ship owners it was inventoried whether ship owners had encountered problems with sediments, and if so whether this would influence their choice for BWT. It could be concluded that especially smaller vessels, with low double bottoms, accumulate sediments. These sediments are costly to remove.

Most ship owners remove the sediments just before going into dock, every 2.5 years. The ship's crew removes the sediment manually.

An additional problem associated with sediments in ballast tanks is Microbially Influenced Corrosion (MIC). MIC can cause rapidly accelerated corrosion in ballast tanks which are poorly coated, or where the coatings are damaged.

Sediment is mostly taken up near river mouths: especially the English rivers which are notorious for heavy sediment loads (Thames, Humber).

Most ship owners indicated that if BWT would solve this sediment problem for them, they would be more interested in installing BWT.

4 TECHNICAL CONSTRAINTS AND POSSIBILITIES

In order to assess the market for BWT, and determine whether to invest in a certain technique, it is important to know the variety of vessels that sail in the world and their different properties. The world fleet will be presented in chapter 5, but this chapter provides an overview of different vessel types and their characteristics. The data is derived from a project by ROYAL HASKONING that is financed by the Royal Association of Netherlands' Ship owners (RANS)[2]. Besides vessel characteristics, a characterisation is given of influent waters to be expected and a characterisation of the sea- borne environment.

4.1 Ships characteristics

4.1.1 Needed capacities

The table below (table 2) summarises the properties of analysed vessels in the ship owners survey for the RANS. The results are described on the following page.

Table 2: Relevant vessel data from a ship owners survey and additional sources.

Type	Gross tonnage (tons)	Deadweight (tons)	Length	Volume ballastwater tanks (m^3)	Capacity pumps (m^3/h)
Chemical tankers	29,289	45,650	182	22,841	2 x 750 and 2 x 280
	29,289	45,750	183	21,906	
	4,671	6,430	118	6,430	
	2,140	3,500	91	1,612	1 x 250
	12,273	26,000	148	7,473	2 x 500
	22,415	48,000	182	16,245	2 x 500
	23,109	49,000	175	14,488 (6,150)	2 x 600
Suezmax Crude Carrier	75,000	150,000	274	56,186	2 x 2500
Container feeder (341 TEU)	3,727	4,723	103	2,027	2 x 40 - 120 (2 x 60)
Container (6600 TEU)	80,942	88,669	299	29,983	2 x 600
Container (4150 TEU)	51,931	60,212	293	18,540	2 x 850
Container (4200 TEU)	50,235	59,093	292	16,612	2 x 300 ans 1 x 500
Container (3500-4000 TEU)[3]		50,000-55,000		10,000-13,000	550 (2 pumps)
General cargo	6,170	8,700	132	3,700	1 (+1) x 250
	5,974	9,498	113	2,257	2*300
Special transport carrier	29,193	45,402	190	80,091	4 x 2,000
	13,110	12,928	159	10,814	2 x 500
Cruise ship	82,000	7,200	290	3,000	2 x 50
Ferry	31,598	6,403	179	2,220	2 x 290
Bulk Carrier (Cape Size)[2]		150,000-180,000		50,000-10,000	2000(2 pumps)
LNG Carrier[2]		66,810		55,000	3000(3 pumps)

[2] Project number 42620, report forthcoming in september 2001

[3] Rigby and Taylor (2001)

Capacities required range from 100 m3/h to 8000 m3/h. The average capacity of the vessels studied is 1500 m3/h, but as can be seen the variation between vessel types is very high. On average these vessels take about 11 hours to pump their ballast fully (range 4-25 hours, standard deviation is 5), but again the differences between vessels are large.

4.1.2 Vessel Characteristics

The trade of the vessel causes these differences; it's loading and unloading particularities and its design. In the following table (table 3) these characteristics are outlined (for further detail see report ROYAL HASKONING report nr. 42620 forthcoming in September 2001).

Table 3: Typical vessel characteristics and routing patterns for different vessel types.

Type of vessel	Typical characteristics	Typical routing pattern
Crude tankers (Suezmax/VLCC/ ULCC etc.)	Loaded out, ballast back. Can typically perform BWE without structural problems. Large capacity needed to ballast during unloading/ deballasting during loading	Bulk trade between different regions
Chemical tankers, Product tankers	Parcel trade. Often have different cargo holds, which can be separately loaded/unloaded. Therefore the vessel is rarely fully in ballast. Ballast operations take place in every port of call. Capacities needed are high to keep up with loading/ unloading speed. Chemical tankers have a cofferdam, which serves as a ballast pump room. This provides possible space for BWT. BWE cannot be executed by all these vessels without creating structural problems, especially in partly loaded conditions.	Parcel trade, voyage length varies. Larger vessels sail between different regions; smaller vessels are predominantly coastal/ short sea. World wide trade.
Bulk carriers	Loaded out, ballast back. Typically has structural constraints to perform BWE.	Bulk trade between different regions, often Australia. Worldwide trade
Container ships	Parcel trade: Ballast water is used for stability operations during loading and unloading: never sails under full ballast. Container vessels use a lot of fuel and thus need to compensate for the loss of weight. High capacity needed to perform speedy stability operations. With high deck-load these vessels need high amounts of ballast water.	Parcel trade (containers) between different regions. World wide trade. Only major ports are serviced, one terminal per port.
Container feeders	Parcel trade. Ballast water is used for stability operations. Ballasting pattern can be adjusted to the weather. Due to high deck load, these vessels need relatively high amounts of ballast water. For performing BWE these vessels may need to restrict the amount of deck load (less high stacking of containers)	Parcel trade (containers) within regions, short voyages, may visit different terminals within one port.
Dedicated cargo vessels	Irregular loading patterns. Rarely empty voyages.	Regional patterns, but may also be between regions. Difficult to predict
RoRo vessels	Irregular loading patterns, but rarely empty. Ballast water is predominantly used for in port operations.	Predominantly regional trips, liner service
General cargo	Parcel trade, often also container capacity. Irregular loading patterns. Rarely voyages in ballast.	Smaller vessels predominantly regional (~3000 DWT), larger vessels also Intercontinental trips.
Cruise ships Passenger vessels	Ballasting required to compensate for huge on-board consumption of food and drinking water. Low flow rates.	Varying patterns, often regional, cruise ships often in vulnerable marine environments.
Pontoons, heavy lift ships, crane ships etc.	Ballasting required to trim vessel due to sometimes uneven load, or for submerging to pick up a load. These vessels are often not equipped with ballast pumps, but use gravity for ballasting, and air pressure for de-ballasting.	Regional as well as intercontinental trips.

It is clear that these vessels use ballast in different ways. This influences the amount of time that can be taken for BWT, the flow rates required, and the points at which these are needed.

During the ship owner survey, the technical drawings of the different vessels were studied. In addition to the drawings, the interviews with the ship owners provided an idea whether certain treatment methods were deemed possible on the vessels looked at.

Treatment technologies that are being considered are:
- filtration techniques;
- cyclonic separation;
- ultraviolet;
- Chemical Treatment;
- Heat treatments;

A few particularities are worth mentioning separately:
- Regarding Heat Treatment: Heat treatment was not deemed possible for chemical tankers as these often sail with chemicals that are susceptible to polymerisation above certain temperatures (sometimes as low as 30 °C). Ship owners regard heat treatment with suspicion, as they feel that higher temperatures speed up corrosion processes. This can be seen on the fact that plating adjacent to heated fuel tanks need new coatings in a much faster rate than plating on other places.
- Regarding Chemical Treatment: chemicals for BWT are currently under development and some products are being promoted. Dutch ship owners (also mentioned by ICS) feel resistance against these BWT, as they fear advancement of regulations in the next decades (as in the TBT discussion). On these grounds CT is termed less likely.

4.2 Characteristics of Intake Water (influent)

Most techniques that are currently considered as BWT are derived from shore based technologies which are capable of handling influents of constant quality. A major technical constraint to the development of BWT, besides the flow rates, is the high variation of water quality that needs to be treated. Developers of techniques must keep this in mind when deciding to invest in R&D.

4.2.1 Unwanted Items from Ballast Water

A list of unwanted classes of organisms and sediment was derived from previous work by ROYAL HASKONING (ROYAL HASKONING 2001). The components that are discussed as to be included in target organisms for BWT are:

- sediment (incl. organisms and resting stages of phyto- and zooplankton species);
- phytoplankton (e.g. unicellular algae causing harmful algal blooms);
- zooplankton (larvae of mussels, snails, crustaceans (several life stages, including adults), fish);
- bacteria (e.g. *Vibrio cholerae* and other disease agents);
- viruses (disease agents).

Latest discussions have focussed on the larger organisms, thus excluding bacteria, viruses and fungi. It is however unclear what will be included in the standard that is to be adopted. Some countries place heavy importance on the *Vibrio cholerae* bacteria.

The organisms may be removed, killed or deactivated by the treatment technique.

Sediment
The problem with sediment from a risk-based point of view is that it may contain bacteria, viruses and resting stages (cysts). Currently sediment is either washed away during ballasting or de- ballasting or is removed periodically from the ballast tanks (see the passage above). There is a risk of releasing highly contaminated sediment. In some countries the sediment is treated after removal at special reception facilities. Depending on the regulations concerning the discharge of sediment it is beneficial to separate sediment from ballast water at the uptake. In this way sediment is left in the harbour of origin. Preventing sediment from settling out in the ballast tanks has certain advantages for the ship owner. Settled sediment enhances corrosion and prevents complete de-ballasting. Both aspects produce raise exploitation costs for the ship owner.

Removing sediment also increases the performance of most treatment options. Due to this reason, a modular technique that first removes sediment can be advantageous.

Phytoplankton and zooplankton
Phytoplankton and zooplankton are present in ballast tanks in different life stages and positions, they may be found in the sediment, in the water and on the walls. Zooplankton often has several different life stages, which makes it difficult to generalise for this group. The cysts, or resting stages of phytoplankton present a special set of problems in that

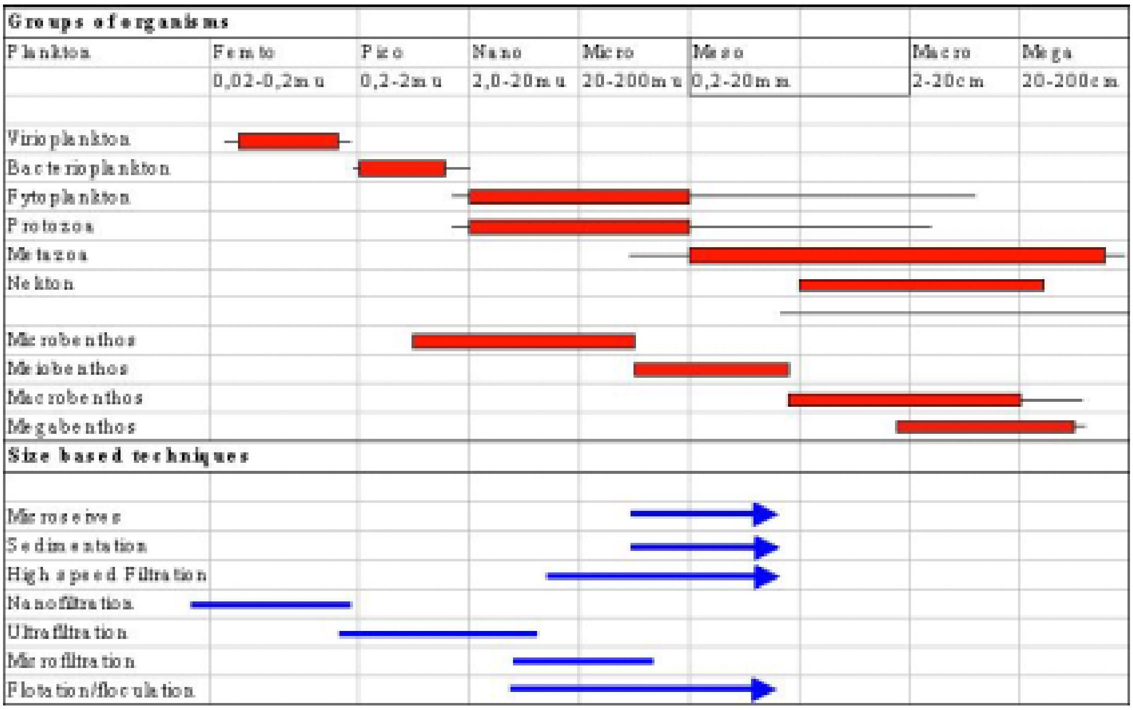


Figure 2: *Size of organisms and effectiveness of filtration methods* (Adapted from: *Sieburth et al. (1978)* Limnol. Oceanogr. *23, and Levine (1985)* Journ. WOCF, *nr. 57,2*

they are extremely resistant to different kinds of treatment and remain viable for long periods of time. Zooplankton is generally larger than phytoplankton.

Bacteria, Viruses
Bacteria and viruses can be found in the ballast water itself, in the sediment and as biofilms along the tank walls. Problems with bacteria are twofold: the spread of human pathogens, as described elsewhere and added corrosion by sulphide reducing bacteria.

Sulphide reducing bacteria (e.g. *Desulfovibrio* sp.) form sulphuric acid, which corrodes steel and coatings. Bacteria and viruses can be removed from the ballast water or rendered non-viable (so they can't reproduce).

The following figure (figure 2) outlines the size classes of organisms that may need to be removed from ballast water.

4.2.2 Varying concentrations

The problem with the treatment of ballast water is not necessarily the organisms and sediment itself. These are relatively well known in different parts of the world. The major problem is the
large variation in concentrations that may be expected around the world.

On the one hand, one may encounter a high loading of clay particles, and on the other hand one might have to take up water amidst an algal bloom. For different treatment options these two examples pose different problems. For example for screening or filtration techniques, a high loading of any matter may cause clogging and render the device useless. For techniques such as hydro cyclones, high loads will reduce the effectiveness. Chemical techniques face dosage problems if the water taken up contains high amounts of organic matter.

UV based techniques will be sensitive to the clarity of the water, and to the amount of organisms in it. A high loading, of for example algae, will cause organisms to create "shade" for one another so that part of the organisms is not affected by the radiation.

Water is often taken up in harbours, which may be infected with sewage effluent from cities. This introduces a new class of organisms, which are not necessarily of marine origin. Sewage often contains high loading of organic matter.

4.2.3 Sea Borne Environments

The BWT will be used on board sea going vessels. Past introductions of technology have shown that it is imperative that the conditions at sea are taken into account during the development of any technique for the shipping industry. As an example, the current situation with refrigerating installations can be looked at. The technology for these installations has been more or less directly transferred from land-based installations. After the ozone layer became an issue it was identified that the sea borne refrigeration installations have high leakage rates. The reason for this lies in part in the sea borne environment.

The situation of BWT on board sea going vessels is characterised by:

- susceptibility to corrosion;
  Corrosion is caused by the seawater, which is used as ships ballast, but also the salty water that may reach the installation by other pathways (eg. the outside of the installations).
- vibrations;
- Any installation on board the ship is exposed to vibrations that are caused by the engine and the propeller. Vibrations can speed the process of metal fatigue and significantly reduce the lifetime of delicate structures (such as lamps).
- pitching, rolling and slamming
  During a small storm the installation may move meters up and down with the ship for days or weeks. The installation should be designed to take this strain.

- wear;
  Due to the variation in places where the vessel will take in ballast, the installation will handle different amounts of sediment. This will cause wear to the installation, which must be taken into account. Especially in vessels with only a low sea chest, and thus take in water near the bottom of the harbour.
- difficulty in maintenance;
  While the ship is at sea it is difficult for the crew to engage in complicated maintenance procedures. The reason for this is amongst others the ships motion, but more importantly the lack of spare parts on board: no ship can carry all spare parts for all its installations.
- availability of personnel.
  Most ships nowadays sail with skeleton crews and cannot expend crewmembers for extra work on an installation for BWT. Especially during loading and unloading (when most ballast water operations take place) most crewmembers are assigned to other duties.
- availability of space
  Existing vessels have generally minimised excess space. In order to minimise tonnage tax based on GT measurements, ship owners minimise the volume of the vessel that cannot be used for cargo. The volume that is necessary for the engine room, and to obtain the ships hull form is often intensively used by the other ships systems. It is therefore in many vessels difficult to find the room for BWT.

5 THE WORLD FLEET

In this chapter the main characteristics of the world fleet that are relevant to BWT are presented. The expert rounds determined that, besides trade patterns which may vary during the lifetime of a vessel, ship type, size (deadweight (DWT)), age and flag state are probably factors that influence the adoption of BWT. In chapter 6 calculations are performed to determine possible turnovers in the potential market for BWT. This chapter uses the analysis presented below.

5.1 Type distribution

The world fleet consists of a very large amount of ship types. Not all vessel types are relevant for BWT. Some vessels, such as pilot, light house vessels, air cushion ships etc., do not use ballast water. Other vessels are not relevant due to their operating nature; an example of this category is tugs (9,116 vessels) or fishing vessels (13,551 vessels) that mostly return to the same port. A complete list of vessel types as recorded in Lloyds Register of Ships, and their numbers in the world fleet are included as appendix 3.

A selection of ship types was made to include the most relevant vessel types for BWT. Some vessel types were grouped under more general names for ease of analysis (for example the type “bulk carriers” includes stone carriers, aggregate carriers, alumina carriers and others). Some vessels were more difficult to categorise and were included in a more general category, these categories were excluded from further analysis (miscellaneous tankers and miscellaneous vessels, see appendix 3) due to their large variety, and due to their small numbers. Special transport vessels, such as crane ships and heavy load ships were also excluded in the statistical analysis.

Table 5 shows the vessel types that were regarded as relevant of BWT for the purpose of the research.

Table 5: main relevant vessel types in the world fleet, and their numbers	
Grouped as:	Total in world fleet
Bulk Carriers	7,050
Container Ship	2,648
Crude Oil Tanker	1,815
Chemical Tanker	1,322
Chemical / Oil Products Tanker	1,242
General Cargo Ship	17,491
LNG Tanker	131
LPG Tanker	1,010
Passenger (Cruise) Ship	358
Passenger –Passenger/cargo (RoRo)	2,942
Passenger Ship	2,793
Oil Products Tanker	5,376
Refrigerated Cargo Ship	1,451
Ro-Ro Cargo Ship	893
Livestock Carrier	123
Vehicles Carrier	583
Total:	47,228

The table shows that the most numerous ships that will probably need BWT are general cargo ships, bulk carriers and oil products tankers. General cargo ships are, in part regional trading, as described in chapter 3. Cruise ships are a smaller category.

5.2 DWT distribution

Deadweight (DWT) is a measure for the size of a vessel. The size of a vessel determines its ballast water holding capacity and thus indirectly its requirements for BWT. In addition, it can be assumed that the smaller classes of vessels only trade regionally and are therefore not relevant to BWT. In this analysis it is assumed that vessels less than 1000 tonnes DWT are not relevant to BWT. Figure 3 shows that a very large part of the registered world fleet is relatively small (0-300 DWT). About one third of the fleet is smaller than 1000 DWT (table 6).

It is important to recognise that Lloyds Register does not contain DWT information on all vessels (some 27,000 vessels have no data on DWT), these vessels mostly belong to vessel types not relevant to BWT (of these 27,000, only 3359 are merchant fleet vessels).

Table 6: DWT Distribution of the world fleet (only vessels with DWT known)

DWT	Vessels	% of fleet
0-300	13001	19,9
300-600	8124	12,4
600-1000	5656	8,7
1000-2000	9145	14,0
2000-3000	3957	6,1
3000-5000	5456	8,4
5000-7500	3836	5,9
7500-10000	1933	3,0
10000-25000	5330	8,2
25000-50000	4835	7,4
50000-75000	1824	2,8
75000-100000	696	1,1
100000-150000	608	0,9
150000-200000	415	0,6
200000-250000	83	0,1
250000-300000	292	0,4
>300000	149	0,2
Total:	65340	100

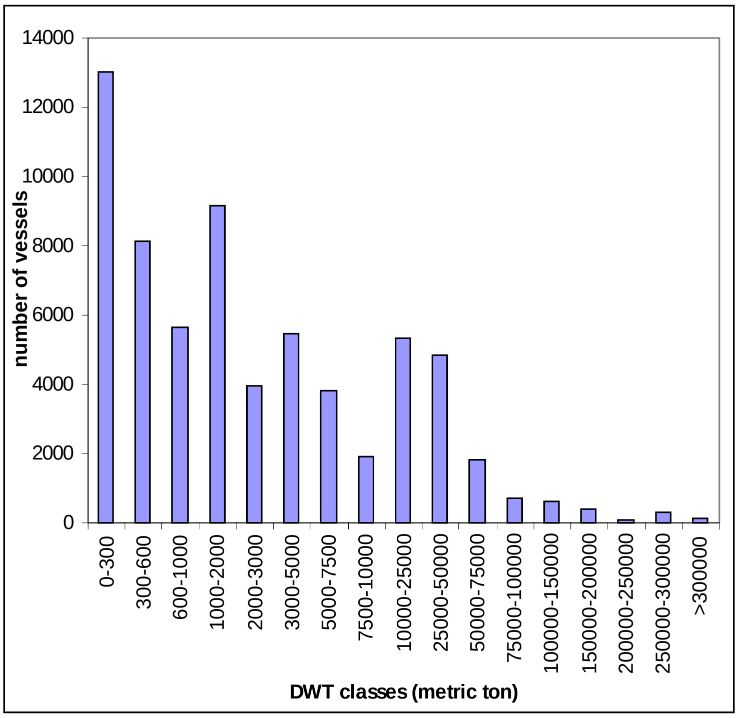


Figure 3: *distribution of deadweight in the world fleet*

5.3 Age distribution

Vessel age is an important factor to determine the relevance to BWT. On a ship that is near scrapping age, the retrofit of a BWT installation will not be economically viable. These vessels will in most cases elect to use BWE as an alternative to comply to ballast water regulations. On the other hand the older the vessel, the more likely it is that its owner will require new building of a vessel and will then face the choice of fitting BWT. From the expert rounds it was concluded that retrofit could only economically be considered for vessels of 10 years and younger. This conclusion is of course very subjective, as it is dependent on many aspects. For instance the way a ship owner operates his vessel, and most of all the costs involved with retrofitting BWT. The average scrapping age for ships is about 25 years. Therefore (for the frame of this study) there are two categories of ships that are of interest to the BWT market analysis: ships younger than 10 years, and ships older than 25. These categories are elaborated further in chapter 6.
Figure 4 shows the age distribution of the relevant vessel types that are over 1000 DWT. Separate analysis of the age distribution of the different vessel types is of interest to producers of installations for a certain market segment. Figure 5 on the next page shows bar charts depicting the age distribution of different vessel types (over 1000 DWT only).

All vessel types (except cruise vessels and container vessels) show that 16- 25 years ago large numbers of ships were built. These vessels will reach scrapping age in the next 10- 15 years.

Observations on the age profiles of vessel types are:
- LNG and LPG tankers which have relatively young fleets, with a peak in the class mentioned above;
- General Cargo vessels form a relatively old fleet, with a majority of vessels older than 20 years;

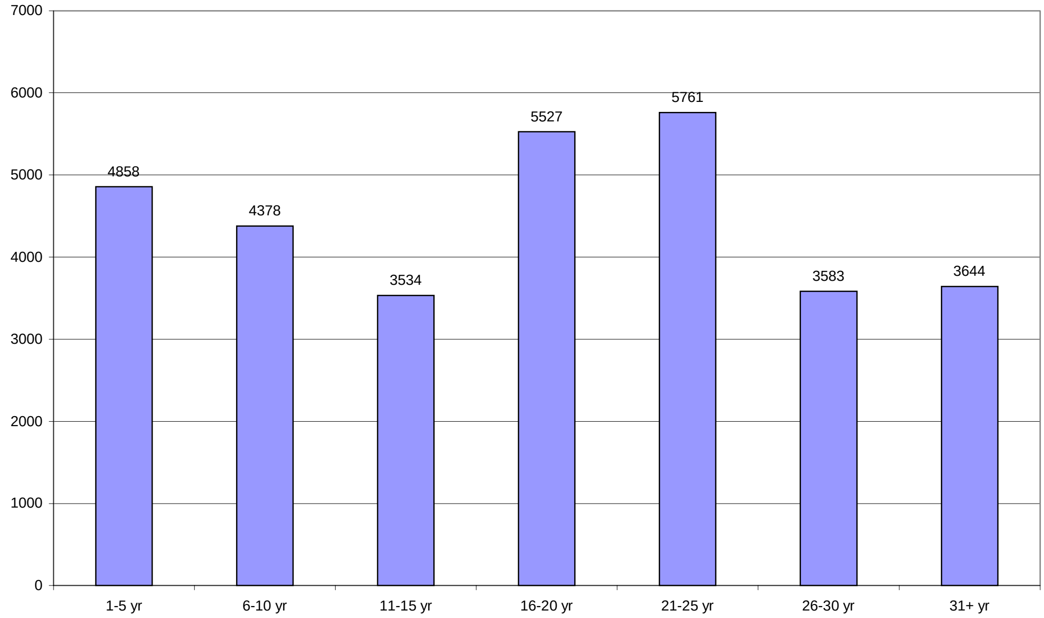
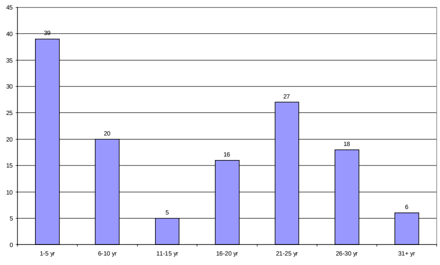


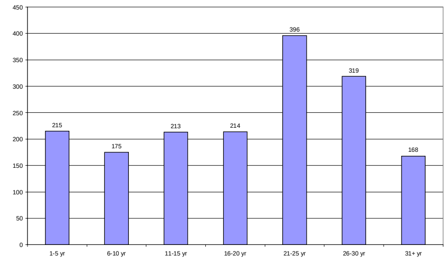
Figure 4: *age distribution of vessels relevant to BWT over 1000 DWT*

Figure 5: *age profiles of different vessel types*

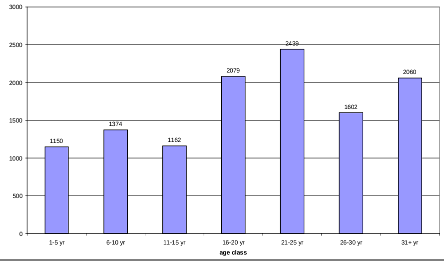
LNG tankers



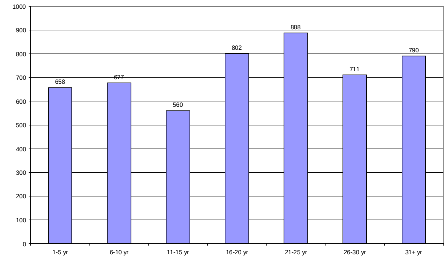
RoRo



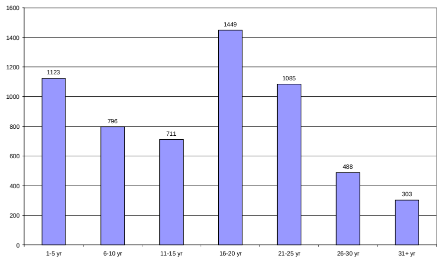
General Cargo



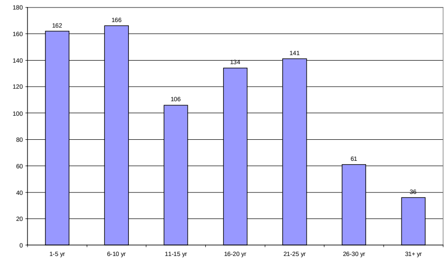
Product Tankers



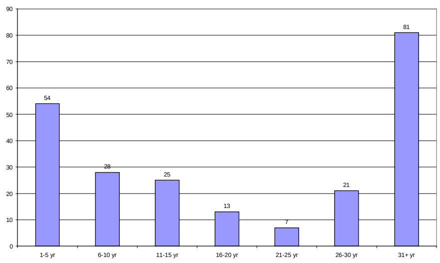
Bulk Carriers



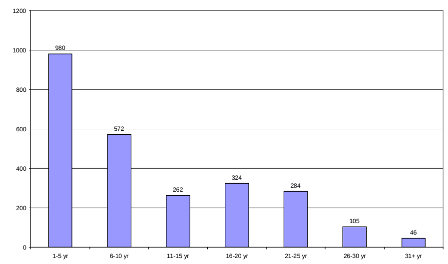
LPG Tankers



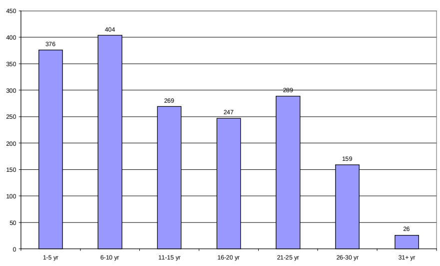
Cruise Ships



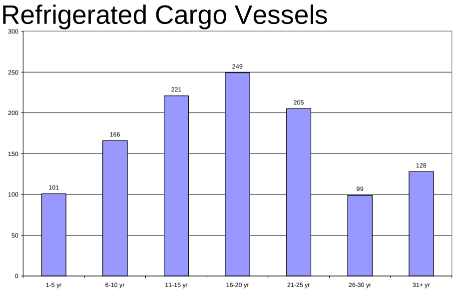
Container Ships



Crude Carriers



Refrigerated Cargo Vessels



1 - 5	6 -10	11-15	16-20	21-25	26-30	> 31

Age classes (years)

5.4 Flag states

It is assumed in the calculations that for early adoption a ship owner needs two aspects. First of all he needs a certain level of awareness concerning the developments in ballast water regulations. Second of all he needs to have sufficient funds to finance the adoption of BWT. The advantage of early adoption in new built vessels for the ship owner is that he will not need to retrofit the BWT later on.

For calculation purposes it was necessary to choose a category of flag states that is likely to meet the requirements of finance and awareness. To remain objective a choice was made to select the countries identified as "high-income" by the World Bank. This is a group of 52 countries selected on economical criteria.

The World Bank uses gross national income (GNI) as main criterion for classifying economies. Based on its GNI per capita, every economy is classified as low income, middle income (subdivided into lower middle and upper middle), or high-income. Other analytical groups, based on geographic regions and levels of external debt, are also used. Classification by income does not necessarily reflect development status of the country. The countries in the high-income category are listed in table 7.

Table 7: *High-income countries based on World Bank criteria.*

Andorra	Germany *	New Caledonia
Aruba	Greece	New Zealand
Australia	Greenland	Northern Mariana Islands
Austria *	Guam	Norway *
Bahamas, The	Hong Kong, China	Portugal
Barbados *	Iceland	Qatar
Belgium	Ireland *	San Marino
Bermuda *	Israel	Singapore *
Brunei	Italy	Slovenia
Canada	Japan *	Spain
Cayman Islands	Kuwait	Sweden *
Channel Islands	Liechtenstein	Switzerland
Cyprus	Luxembourg *	United Arab Emirates
Denmark *	Macao, China	United Kingdom *
Faeroe Islands	Malta	United States *
Finland *	Monaco	Virgin Islands (U.S.)
France *	Netherlands *	
French Polynesia	Netherlands Antilles	

* These countries are on the White List of Paris MOU (flag states with a consistently low safety, health environmental detention record)

Looking at the age build-up of the fleets of the high-income countries it is clear that higher income countries have much younger fleets. Whereas these countries have about 38 percent of the BWT vessels, their part in the world fleet (relevant to BWT, above 1000 DWT) of younger than 10 years is just under 50 %. The average year class (vessels built in one year) for these countries amounts to 454 vessels.

Table 8 here below shows the amount of vessels belonging to the high-income countries, and their percentage in the world fleet.

Table 8: *Ship types in the world fleet, their numbers and their numbers above 1000 DWT.*

Ship Types	**Worldfleet Above 1000 DWT**	**Above 1000 DWT, high-income (number(% of total))**
Bulk Carriers	6,143	2492 (19.4)
Container Ship	2,629	532 (4.1)
Crude Oil Tanker	1,802	439 (3.4)
Chemical Tanker	901	1131 (8.8)
Chemical / Oil Products Tanker	1,221	948 (7.4)
General Cargo Ship	11,919	3603 (28.1)
LNG Tanker	131	27 (0.2)
LPG Tanker	816	64 (0.5)
Passenger (Cruise) Ship	235	368 (2.9)
Passenger -Passenger/cargo (RoRo)	981	1371 (10.7)
Passenger Ship	52	145 (1.1)
Oil Products Tanker	3,898	619 (4.8)
Refrigerated Cargo Ship	1,181	19 (0.1)
Ro-Ro Cargo Ship	825	397 (3.1)
Livestock Carrier	92	441 (3.4)
Vehicles Carrier	566	241 (1.9)
total	*33,392*	12837 (38,4)

6 MARKET CALCULATIONS

6.1 Approach

The expert rounds clearly showed that the world fleet is very complex, and that adoption of BWT is dependent on many different factors, which differ per vessel and per ship owner. The purpose of this study is however to provide as much insight into the BWT market as possible and to stimulate investment in R&D. For this purpose a calculation of the potential market for BWT has been made in this chapter.

In the previous chapters the structure of the world fleet was shown. In order to translate these aspects to the world fleet a few assumptions must be made:

- A standard for BWT will be set in 2003. Before that the market for BWT will be very limited. Although some ship owners are willing to invest in R&D and shipboard trials.
- After 2003 BWT can be type approved, but the convention will not be of force until it is ratified.
- Then, looking at the current developments in unilateral legislation, ship owners will already have to choose between BWT and BWE when sailing on different destinations. It is assumed that unilateral legislation will be (largely) in line with the standard set in the treaty.
- The market after 2003, until the convention comes into force, is restricted to new buildings and retrofit of ship owners with sufficient awareness and financial resources to invest in BWT.
- Retrofitting will only take place when the economic lifetime of the ship is long enough to “earn back” the capital costs of the installation. We have assumed that this is valid for vessels younger than 10 years.
- Retrofit after 2003 is only deemed feasible for vessels less than 10 years of age and belonging to the 52 high-income countries.
- The convention will enter into force about five years after its signing in 2003. Meaning that after 2008 all vessels will have to comply.

Although all assumptions are open for debate there are certain indications that the ratification process will take less than the five years assumed in this report. Effects that are the result of this will be addressed in chapter 8.
Figure 5 shows the approach chosen in the analysis. In the previous chapter the entire fleet is presented and a qualification of relevancy to BWT is given based on ship type and size (step 1). After this analysis, the short-term market is analysed on the criteria awareness and financial resources (step

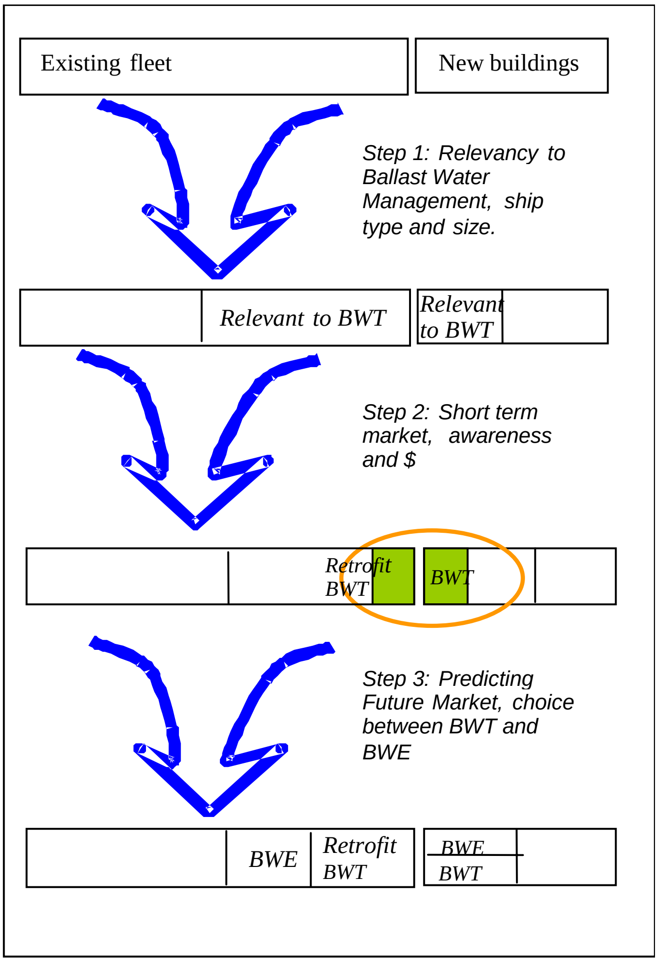


Figure 5: *Analysis steps in calculating the potential market for BWT*

2). The third step regards the market after 2008, which is valid for all internationally trading vessels (step 3). The choice always remains between implementing BWT and BWE.

6.2 Step 1: Vessels relevant to BWT

Step one consists of selecting the relevant ship types above 1000 DWT. Ships above 1000 DWT are assumed to be engaged in international trade. The numbers of these vessels are listed in table 1. In total these vessels, form 37% of the world fleet, but 70% of these vessel types. The largest category is still the General Cargo vessels

Table 9: *Ship types in the world fleet, their numbers and their numbers above 1000 DWT.*

Ship Types	**Total in Worldfleet**	**Above 1000 DWT**
Bulk Carriers	7,050	6,143
Container Ship	2,648	2,629
Crude Oil Tanker	1,815	1,802
Chemical Tanker	1,322	901
Chemical / Oil Products Tanker	1,242	1,221
General Cargo Ship	17,491	11,919
LNG Tanker	131	131
LPG Tanker	1,010	816
Passenger (Cruise) Ship	358	235
Passenger –Passenger/cargo (RoRo)	2,942	981
Passenger Ship	2,793	52
Oil Products Tanker	5,376	3,898
Refrigerated Cargo Ship	1,451	1,181
Ro-Ro Cargo Ship	893	825
Livestock Carrier	123	92
Vehicles Carrier	583	566
Total	*47,228*	*33,392*

6.3 Step 2: Potential short-term market

The major driving force until 2008 is considered to be unilateral legislation. It is assumed that once a standard for BWT is set in 2003, most unilateral legislation will follow this approach in anticipation of ratification. Vessels sailing on these countries will have to choose between BWT and BWE. It is assumed that only those ship owners with sufficient awareness and financial means can consider BWT before the convention is in effect.

In step 2 the vessels relevant to BWT are selected on the criterion of awareness and financial means to determine the short-term market (i.e. before 2008, see 6.1). In order to do this, the vessels under the flag of the 52 high-income countries are selected. Two groups can be identified: a group that could potentially consider retrofitting, and a group of vessels that will probably be phased out and thus replaced by new vessels. Possible fleet developments (increase/decrease) have not been taken into account, as these are very dependent on market circumstances (e.g. oil), and mostly only valid for a short number of years.

Table 10 shows the number of vessels relevant to retrofit between 2003 and 2008, above 1000 DWT and sailing under the flag of the 52 high-income countries. Per year this means that on average 676 vessels that may be eligible to retrofit of BWT. Of course the choice remains between BWT and BWE. *(Table 14: Short term calculation)*

Table 10: *vessels relevant to retrofit between 2003 and 2008, (younger than 10 yrs in 2003, above 1000DWT, 52 richest flag states).*

Ship Type	**Number**
Bulk	574
Container Ship	550
Crude Oil Tanker	271
Chemical Tanker	86
Chemical / Oil Products Tanker	198
General Cargo Ship	974
LNG Tanker	19
LPG Tanker	86
Passenger (Cruise) Ship	41
Passenger – passanger/cargo (RoRo)	143
Passenger Ship	4
Oil Products Tanker	249
Refrigerated Cargo Ship	29
Ro-Ro Cargo Ship	85
Livestock Carrier	2
Vehicles Carrier	73
Total:	*3,384*

For new build vessels, the number of vessels that are above the average scrapping age (25 years) is deemed relevant. Between 2003 and 2008 new build of the high-income countries are a potential market for adoption of BWT. Table 11 shows the numbers of vessels that reach the average scrapping age before 2008. The number of vessels that can potentially be phased out before 2008 amounts to 16,903 (see table 11). This means that on average 2415 p/a vessels would be scrapped (from 2001 to 2008, 7 years). Other sources suggest that, this is an over estimation (see table 12), and is caused by the calculation method which assumes that all vessels of, older than 25 years, will be phased out between now and 2008; this is not realistic.
The average size of a year class in BWT ships is 1054 vessels (for vessels up to 25 years of age). It can be expected that this figure predicts the amount of new build in the future better. *(Table 14: Mid term and long term calculation)*

Assuming symmetry of the world fleet (at least more or less valid for ships up to 25 years of age) the number of 2415 vessels can be kept as the amount of vessels under 10 years of age available for retrofit in the long run. *(Table 14: Mid term calculation)*

For high-income countries the number is much lower, probably also due to newer fleets. For these countries the number of vessels that could potentially be phased out amounts to 4709, meaning 672 vessels a year (from 2001 to 2008, 7 years). An estimate for the number of new buildings that will take place for the relevant flag states between now and 2008 would be below this number. The average size of a year class of vessels from the high-income countries is 454 vessels. The fleets of these countries are relatively new in comparison to the rest of the fleet. *(Table 14: Short term calculation)*

Table 11: *New build until 2008 (vessels reaching the average scrapping age (25 years) by 2008), high-income countries and world fleet.*

Ship Types	**Numbers high-income countries**	**Numbers world fleet**
Bulk Carrier	974	2,638
Container Ship	240	606
Crude Oil Tanker	343	647
Chemical Tanker	134	378
Chemical / Oil Products Tanker	142	361
General Cargo Ship	1,326	7,282
LNG Tanker	29	62
LPG Tanker	109	329
Passenger (Cruise) Ship	70	118
Passenger – passanger/cargo (RoRo)	298	569
Passenger Ship	14	25
Oil Products Tanker	593	2,531
Refrigerated Cargo Ship	121	576
Ro-Ro Cargo Ship	235	502
Livestock Carrier	21	81
Vehicles Carrier	60	198
Total:	*4,709*	*16,903*

6.4 Step 3: potential long term market

In the long run, after ratification of the future ballast water convention, most ship owners will have made the choice between BWE and BWT. If developments in BWT are sufficient progressive, unilateral legislation is likely to demand BWT, because of its advantages in verifiable effectiveness.

In the long run, BWT may be deemed interesting for all of the internationally trading world fleet. The potential long-term market will consist of new build, and existing vessels that have not yet retrofitted BWT. The last category is difficult to predict for the future, as it is very much dependent on the developments in legislation, and the availability, applicability and cost of BWT techniques. The amount of new buildings is easier to determine using estimates on scrapping rates in the world. Table 12 shows a prediction for the next 15 years (for a limited number of ship types)

Since these figures cover only a part of all ship types, the size of an average year class (1,054) is used in the further calculations.

Table 12: *World fleet scrapping requirements in a 15 year perspective* (Fearnleys (2001)

Year	Total (No.)	Tankers (No.)	Bulk Carriers (No.)	Dry Cargo (No.)	Combos (No.)	Gas Tankers (No.)
2001	757	199	227	203	23	8
2002	757	199	227	203	23	8
2003	598	155	179	240	18	6
2004	598	155	179	240	18	6
2005	598	155	179	240	18	6
2006	598	155	179	240	18	6
2007	541	141	163	216	16	5
2008	541	141	163	216	16	5
2009	541	141	163	216	16	5
2010	541	141	163	216	16	5
2011	541	141	163	216	16	5
2012	368	96	110	147	11	4
2013	368	96	110	147	11	4
2014	368	96	110	147	11	4
2015	368	96	110	147	11	4
Average:	*579*	*151*	*174*	*232*	*17*	*6*

6.5 Turnover estimations

The next step in the market analysis is to estimate potential turnover for the market on BWT. As stated previously, this exercise is highly dependent on many variables. Therefore the calculation is kept simple, and thus as robust as possible.

For turnover calculations the number of vessels is multiplied by an average cost per ship. At present the level of experience with BWT is so little that other, more detailed methods of calculation (for instance taking ship type and size into account) are not deemed credible. The average cost is calculated based on available data of BWT. And averaged over the different capacities. The available data is shown in table 13. Installation costs will not be taken into account, since these vary widely due to the specific characteristics of every individual ship.

Table 13: available cost estimates for BWT

Type of treatment	Pump capacity (m3/h)	Capital Cost (US$)	Estimated installation costs (US$)
UV irradiation*	100	90,000	
UV irradiation*	200	140,000	
UV irradiation*	350	160,000	34,000
UV irradiation*	500	210,000	30,000
Recirculating heating system#	515	200,000	91,000
UV irradiation*	750	270,000	
UV irradiation*	1,000	310,000	
UV irradiation*	2,000	475,000	
UV irradiation*	3,000	700,000	
Average:	935	283,889	

*System based on a BWT consisting of a Separator for pre-treatment and UV irradiation as the main treatment. No installation or commissioning charges are included. Source: Birgir Nilsen (OptiMarin A.S.).

Data from Taylor and Rigby (2001) AQIS report No. 13.

The data in table 13 suggests an average unit cost for a complete BWT solution to be about 283,000. The average pump capacity for which these data are valid is 935 m3/h. To obtain a figure for calculations, the weighed average of the relevant BWT vessels was calculated. This amounted to 12,069 DWT, which according to our ship survey (see table 2) corresponds to a ballast volume of about 4000 m3 and a needed pump capacity of between 600 and 1000 m3/h (looking at the vessels closest to 12,069 DWT).

Calculations on chemical techniques resulted in a price of about 300,000 USD over the lifetime of the vessel (for Degaclean® (Degussa A.G.) a price is cited of 150 USD per 1000 tonnes of ballast water. The calculation is valid for a general cargo vessel of about 12000 DWT with 4000 tonnes of ballast water with about 20 (port-port) trips a year and a lifetime of 25 years).

In the calculations two scenarios are distinguished: a lower estimate and a higher estimate. The lower estimate scenario remains on the conservative side, here the average cost of an installation is set on 200,000 USD (using the lower estimate for an installation of just under 600 m3/h, see table 13). In the higher estimate scenario the average cost of an installation is set on 310,000 USD (lower estimate for an installation of just under 1000 m3/h, see table 13)

The three time phases used are 2001- 2003, meaning before adoption of a standard for BWT, 2003-2008, standing for the time between signing and ratification of the ballast water convention and 2008 and onwards, meaning after entry into force of the convention.

Table 14: vessels eligible for BWT and potential turnover

Year	Market	Number of vessels/year	potential turnover (mln. USD/year)	
			Lower estimate	Higher Estimate
2001-2003	Marginal R&D based market	Few		
2003-2008	Retrofit of vessels younger than 10 years of high-income countries	676	135	210
	New Buildings of high-income countries	454	91	141
	total:	**1,130**	**226**	**350**
2008 and further	Retrofit of vessels younger than 10 years	2,415	483	749
	All New Buildings	1,054	211	327
	total:	**3,469**	**694**	**1075**

From 2003 until 2008 (IMO treaty into effect) the potential market is estimated to be between 226 and 350 million USD/yr. (*short term*) The total potential market for these five years is estimated between 1.1 and 1.8 billion USD.

From 2008 the potential market for Ballast Water Treatment is estimated to be between 694 million and 1 billion USD/yr. (*mid term*) This potential market applies to approximately 55 % of retrofitting existing ships.

After all the existing vessels have been retrofitted the potential yearly market (on new buildings) could amount to 211 million up to 327 million USD/yr. (*long term*)

The above forecasts depend upon many factors, which will be discussed in the next chapter. The most important aspects influencing possible turnover are the availability of techniques superior (in all aspects) to BWE, and factors of enforcement of legislation. Market penetration is also important.

7 DISCUSSION AND CONCLUSIONS

This study is an attempt to provide an insight into the market for BWT, its possibilities and constraints. The report provides background information on background opinions of ship owners, technical aspects of selected vessels and information on the situations in which BWT will have to operate. The world fleet is presented with its made-up, and characteristics that determine whether the vessel will be likely to consider adopting BWT. This chapter summarises the main findings and their limitations.

7.1 Potential market

For the potential market it was important to determine a time frame for the adoption of BWT legislation. It was decided to set the date for the signing of an IMO convention in 2003 and its ratification five years later, in 2008. These moments determine which vessels will adopt BWT. Until 2008 unilateral legislation, as in the USA, will be the main driving force for a ship owner to consider BWT. After 2003 a standard for BWT will be determined and can guide separate countries to determine which installations can be approved, and which vessels can not.

The potential market for BWT consists of newly built vessels and of vessels in which BWT may be retrofitted. Until 2003 it is assumed that very few vessels will adopt BWT. If so this will be mainly on a trial basis. This can be done by large ship owners who decide to test the impact of BWT for their entire fleet. There is however no guarantee that the installations fitted before 2003 will be approved after that date.

Between 2003 and 2008 the market will consist of those ship owners that can anticipate the oncoming convention and must perform BWE due to unilateral legislation. In order to do this they need awareness, and sufficient financial means. The ship owners that meet these requirements are probably inhabitants of wealthier nations. For this reason the fleet of ‘high-income’ countries (according to the world bank) was looked at. It is assumed that in the period 2003- 2008 these ship owners will consider placing BWT on new built vessels and retrofit on young vessels (under 10 years of age). This results in a market of 1130 vessels per year, which at 200,000 USD per vessel (over its lifetime) means a potential yearly market for BWT of 226 million USD. *(lower estimate)*

After 2008 all internationally trading vessels that use seawater as ships ballast will fall under the IMO convention on ships ballast water. The market then consists of all vessels that can consider installing BWT. In this study it is assumed that this is valid for new built ships, and for vessels less than 10 years of age. Other ship owners may decide to apply BWE due to the high capital cost involved in BWT. The size of this market comprises about 1054 new built vessels per year and a group of 2415 young vessels, resulting in a potential turnover of 694 million USD per year.

It can be concluded that the market for BWT is large, and diverse. The diversity of ship types and sizes combined with different possible wishes of ship owners will result in a market, which has room for many different techniques. The time available for development is pressing, as in 2003 a standard will be set which will, for both ballast water quality and ballast water techniques, indicate which techniques will be approved. The techniques developed after that date will need to have additional advantages over other already approved techniques.

7.2 Uncertainties and constraints in the market

Legislation

Uncertainties for the development of BWT are still plenty. First of all it is unclear whether the assumption of the signing of the ballast water convention is feasible in 2003. As yet no standard has been agreed on. At the same time the certification of BWT will be dependent on the technical code that will be agreed upon in the convention.

The short-term market is primarily dependent on the developments in unilateral legislation. Sales will depend on for instance the acceptance of BWT as an alternative to BWE by port states. The US Coast Guard is presently undertaking the first developments in this direction.

The convention will also decide on when vessels are to comply to ballast water management options.

Many countries are pushing for rapid entry-into-force schedules. It may well be agreed at the convention that the treaty comes into force before 2008. With the result that the potential market will reach our estimated 2008 level (1 billion USD/yr) even before 2008.

Market Penetration
A major aspect that will determine the success of BWT introduction from a manufacturers point of view, is the access to ship owners all over the world. Ship owners must be contacted directly by suppliers they trust, to purchase equipment. Therefore a successful marketing strategy that uses agents in different countries is essential.

Technical Constraints
BWT still faces different technical challenges in order to provide a sound alternative for BWE. The main difficulties are related to flow rates in combination with the unknown loading rates. Vessels take up ballast in a wide variety of regions, which have many different types of water, with different concentrations of organisms and sediments. In order to guarantee sufficient reduction of the risk of unwanted introductions an additional capacity will have to be installed to handle high loading situations.

Experience with other installations (e.g. refrigerating equipment, oil-water separators) suggests that it is imperative to take the shipboard environment into account in a very early stage of development. The corrosive surroundings, vibrations, lack of space, time, spare parts and other essentials can cause the introduction of an unprepared BWT to become a disaster. An example of an aspect that one must be aware of is that many vessels extract ballast water and engine cooling water from the same sea chest. In situations of conflict (not enough water), the engine gets priority and less water is available for ballasting. A BWT designed for steady flow rates may then cause problems.

7.3 Choice between BWE and BWT

It is likely that BWE will remain an option open to ship owners for some time to come. Because of this they will always be able to choose between BWT and BWE. The outcome of this choice will be primarily dependent on availability of techniques better or more economical than BWE.

A Dutch ship owner estimated the cost for BWE for a double hull tanker with 10 tanks amount to about 8300 USD per exchange, not taking fitting costs (120,000) for additional valves and piping into account.
Rigby and Taylor (2001) compiled a list of estimated costs for different techniques of BWT and BWE. Their estimates for ocean exchange (empty- refill) range from 0.61 to 1.56 USD cents per m3 of ballast water. The average of their estimates is 1,11 USD cents, which in a vessel of 12000 DWT and 4000 m3 of ballast water would amount to 4400 USD per voyage.

The table in Rigby and Taylor (2001) shows that for BWE, capital costs are only present if alterations are made for continuous flushing or the Brazilian dilution method. Although operational costs of BWE are estimated to be higher than for BWT, the capital costs of BWT cause it to end up with much higher overall costs. Taking the overall cost overview into account, at present ship owners will probably decide to continue with BWE for existing vessels.

For the Dutch ship owners with sediment problems it can however be stated that BWT has additional financial advantages due to the reduction of sediments in their tanks. Sediments can therefore be a reason for a ship owner to accept higher initial capital costs.

In conclusion, it can be stated that that BWT appears to have higher initial investment costs than BWE, but does have advantages that might reduce operational costs. If the costs of BWT reduces as a result of new developments (R&D), the choice would more often be made in favour of BWT.

7.4 How to reach success?

On the road to producing a treatment option for ballast water there are still many obstacles that can only be overcome by research and development and successful marketing. The main conclusion from this study is that there is a huge market for BWT and that it is diverse enough to accommodate many different BWT. In order to sell a BWT to a ship owner, the BWT industry must show that their option has advantages above BWE.

The main driving force for major BWT sales is a globally accepted and agreed upon standard. Based upon this the BWT industry can already anticipate on the future needs of shipowners.

Appendix1
Compilation report 1 expert round

Results expert round 1

In this document, the results of the first Expert Round Survey are presented. Below, the questions as well as a summary and the details of the answers are provided.

Assumptions (given to the respondent)
Assume that at least several port states direct ships to undertake high-seas ballast water exchange or some alternative BWT prior to entering their waters. Also assume that the IMO recommends (as it currently does) that ballast water exchange or alternative treatments be undertaken regardless of the presence of port state requirements. Also assume that some port states have stricter environmental standards for receiving waters than others. Finally, assume that candidate BWT systems are available but not yet utilized by a number of ships, and therefore, not yet "well-proven" operationally or biologically.

Questions

1. Criteria for ship owners

Question What are in your opinion the most important criteria or features for ship owners when considering purchase and installation of BWT equipment? (please sort in order of importance from top (important) to bottom (less important)(use drag / cut&paste)). Ease of on-board construction/fitting Capital Investment cost Operational cost Time needed for operation (process time) Expected life time (economic, technical) Reliability Effectiveness at reducing risk of introduction of species Availability of technical/maintenance services Convenience of operations (need for skilled staff etc.) Acceptance by port authorities Environmentally sound Chemical-free SUMMARY Most important is that technology meet regulations: it must meet the forthcoming IMO standard and must be accepted by port authorities. Second most important criterion is the cost over the lifetime of the investment. Third comes reliability and user-	1.Reliability 1.Operational cost 1.Effectiveness at meeting required standard [reducing risk of introduction of species] 2.Time needed for operation (process time) 2. Availability of technical/maintenance services 2. Convenience of operations (need for skilled staff etc.) 3.Ease of on-board construction/fitting 3.Capital Investment cost 3.Expected life time (economic, technical) * 0.Acceptance by port authorities 0.Environmentally sound 0.Chemical-free Effectiveness at reducing risk of introduction of species/Acceptance by port authorities/Environmentally sound Reliability Operational cost/Capital Investment cost /Time needed for operation (process time)/Convenience of operations (need for skilled staff etc.) Ease of on-board construction/fitting / Availability of technical/maintenance services Expected life time (economic, technical) Most important is the acceptance by port authorities, and is linked to effectiveness and reducing risk of introduction of species. Time needed for operation Ease of onboard construction/fitting for both existing and new vessels Chemical free not necessary as long as acceptable

friendliness.	 Acceptance by port authorities Time needed for operation (process time) Operational cost Expected lifetime (economic, technical) Reliability Effectiveness at reducing risk of introduction of species Availability of technical/maintenance services Convenience of operations (need for skilled staff etc.) Capital Investment cost (new ships only, if retrofitting the most important item) Environmentally sound Chemical-free Ease of on-board construction/fitting (only for new ships, if retrofitting this item the second most important item**)** Acceptance by port authorities Capital Investment cost Operational cost Expected life time (economic, technical) Reliability Time needed for operation (process time) Availability of technical/maintenance services Ease of on-board construction/fitting Effectiveness at reducing risk of introduction of species Convenience of operations (need for skilled staff etc.) Environmentally sound Chemical-free
Additional remarks	

2. Who will be the fist to install BWT?

Question Which flag states? SUMMARY Wealthy nations and the nations with BW regulations in place.	Ship owners of wealthy nations, perhaps Norway Flags of countries with laws in place may come first, but well-managed companies of any flag could be one of the earliest to install. Scandinavian Australia, US and the EU USA, Norway, the Netherlands, Australia, UK etc. In general: Quality Flags.
Question Which types of ships? SUMMARY	Bulk carriers due to vulnerability to officialdom Those with smaller flow rates and/or which are visible to the public will be first: cruise ships, container ships, and oil tankers on the west coast of the US

Cruise ships, bulk carriers, tankers, containers. Least: general cargo and dedicated vessels. Low flows may make adoption of BWT easier.	Tankers, Bulk carriers (australia a lot), Containers Cruise ships, Bulk carriers and Tankers Oil tankers, dry bulk carriers, chemical tankers.
Question Which sizes (DWT)? SUMMARY In future all sizes.	Not realistic to guess (see above) Above 5000 M/T (in the future all sizes) More than handy size 25,000 DWT
Question Which routes? SUMMARY Particularly linked with countries that now have unilateral regulations: USA, Australia, EU countries.	Ships engaged, or offering on Australian trade, or North American trade. (see above) Linked to 14 countries with unilateral approaches Australia, US, South America and the EU Those countries which are enforcing this by law. Besides that countries with large oil and bulk trades.
Question Which age of ships? SUMMARY Primarily new ships, but cruise ships also the older ones.	Primarily, new ships Younger ships are a better investment **New ships only (except for Cruise ships)** Less than 10 years (depends also on investment requirements. Vessels are maybe allowed to be phased out. See discussion regarding Double Hull.
Question Which type of ship owners (size, nature,….)? SUMMARY Particular the larger companies, with their own environmental management systems.	Major independents, Maersk, Bergesen, P&O, Evergreen, StenaBulk, and major cruise lines. Larger Companies, ISO 14000 or similar certificated companies and Cruise operators. Larger ship owners with fleets of say 10 or more vessels.
Additional remarks	

3. New ships, retrofitting in existing ships

Question To what extent do you think ship-owners will wish to retrofit existing ships with BWT to avoid the need to undertake ballast water exchange? (open question) SUMMARY Limited potential, design is often not compatible.	Only if the cost of retrofit is very low <u>and</u> operational costs are markedly lower than exchange, <u>and</u> they have an assured trading pattern that will insist on something being done. None or very limited, this is not likely with the currently available equipment and techniques. However, the market forces and national/regional regulations could demand installations of such retrofitting. Depends largely on investment costs and the ability they can pass on the bill to their customers.
Question	Very low.

How do you view the potential for installing BWT in existing ships?	Very limited
Question How much will ship owners be willing to invest relative to the value of the ship?	Very low. Would indeed very most depend on the age, type and trade of the ship Depends largely on the existing costs related to the use of ballast water (fuel consumption of pumps, wear/teat equipment, hull stress etc.), but as an initial guess: 2-3%.
Question To what extent will they invest in installation on new ships?	100% if legislation is impending and systems exist. Buyers will insist on good exchange systems if no reliable BWT system exists. Would indeed very most depend on the age, type, trade of the ship and the current market situation for that ship type Certainly if countries have this enforced by law and these countries play an important role in their trading/routing patterns.
Question For which ship owners/classes are these potentialities most likely?)	Owners of ships that will trade to nations that have already signaled the intention to require ballast treatment and to monitor compliance. Cruise operators
Additional remarks	This is best answered by the ship owners themselves. In my experience, there is a desire to install on existing ships as well as new ships to avoid BWE requirements. Dependant on regulations. If required to treat, retrofit will be needed. Repressive approach of a certain country, possible convention that BWT necessary is.

4. Countries taking the lead

Question Which countries or regions do you expect to be pioneers in regulating BWT and/or enforcing set standards? (open question) SUMMARY Australia, USA, Brazil, Canada, perhaps Norway.	Australia, Brazil, Canada, New Zealand, USA. Norway may decide to proceed for domestic political reasons, and because they can expect the support of their own ship owners. US, Australia, New Zealand, Brazil Australia and US. (evt Canada) Australia, US and the EU USA, Norway, the Netherlands, Australia, UK etc. In general: Quality Flags.
Additional remarks	

5. Driving forces for ship owners

Question What will be the reasons or driving forces for ship owners to invest in, and use BWT? (please sort in order of importance from top (important) to bottom (less important)(use drag /	1. Legislation requires some action, and I prefer BWT to ballast water exchange. 2. Encountering difficulties in ports that are currently serviced by the ship owner. 3. Clients ask for overall environmental soundness, 'green label'

cut&paste)) Clients ask for overall environmental soundness, ‘green label’ Want to be a ‘responsible ship owner’ Legislation requires some action, and I prefer BWT to ballast water exchange Clients ask for BWT specifically Access to new countries and regions Do not want to be a ‘sub-standard ship owner’ Encountering difficulties in ports that are currently serviced by the ship owner SUMMARY In the first place the BW regulations ship owners have to comply with in order to gain/maintain access to a certain market. Environmental awareness and progressiveness form sometimes a secondary drive.	3. Want to be a 'responsible ship owner' 3. Clients ask for BWT specifically 0…Access to new countries and regions 0. Do not want to be a 'sub-standard ship owner'. Legislation requires some action, and I prefer BWT to ballast water exchange/Encountering difficulties in ports that are currently serviced by the ship owner/Access to new countries and regions Clients ask for overall environmental soundness, 'green label'/Want to be a 'responsible ship owner'/Do not want to be a 'sub-standard ship owner' Clients ask for BWT specifically Legislation requires some action Access to new countries and regions Encountering difficulties in current ports. Encountering difficulties in ports that are currently serviced by the ship owner Clients ask for BWT specifically Access to new countries and regions Clients ask for overall environmental soundness, 'green label' Legislation requires some action, and I prefer BWT to ballast water exchange Want to be a 'responsible ship owner' Do not want to be a 'sub-standard ship owner' Access to new countries and regions Encountering difficulties in ports that are currently serviced by the ship owner Clients ask for BWT specifically Do not want to be a 'sub-standard ship owner' Clients ask for overall environmental soundness, 'green label' Want to be a 'responsible ship owner' Legislation requires some action, and I prefer BWT to ballast water exchange
Additional remarks	Assuming that “Access to new countries and regions” means to areas where BWT is a requirement for existing ships. The item “Do not want to be a 'sub-standard ship owner'” is misleading, this would only apply if BWT where ruled to be an international requirement for existing ships.

6. Success of BWT

BWT introduction should have realistic and preferably operational and measurable objectives for ship owners.

Question From a ship owners perspective, how would you measure the potential for success of a proposed BWT? What kind of indicators would you propose (fleet coverage, costs, availability for vessel type)? (open question) SUMMARY Reliable systems with high capacity available on the market. Emerging performance of equipment. Standards and certification a fact.	A proven capability, with certification by a respected body. The system should be based on a known technology, and be backed by a known engineering firm. Not a ship owner, but would imagine that shipboard performance and reliability at pilot scale would be the first predictive indication, then biological performance data, shipboard tests, cost estimates, and availability to a variety of vessels. By the International regulations and standards, as well to some extent the cost involved High capacity, compliance with regulations and standards, low investment and low maintenance cost Costs, trading flexibility, earning capacity
Additional remarks	Most important is flow rate. Capacity lacking.
Question When would you call an introduction of a BWT in the market place a success? (open question) SUMMARY Regulations in place and equipment being installed & used.	When it is specified by a ship owner in a new building contract, or by a Coastal State as being acceptable. When it has been approved by the IMO or a port state as meeting treatment requirements for a certain class of ships. Effective and volume friendly and acceptance by legislation **That would depend on the BWT market mechanisms (competitors and the overall shipping market in general)** **If a similar approach is taken and implementation scheme is introduced as f.i. the double hull tankers.** **Ratification of IMO member states.**
Additional remarks	

Other remarks

	Differentiation Differentiation with BWT: in risk areas, might influence acquiring BWT. Vessels Charters: in Charterparty will specify BWT needed due to route changes: so vessels will install independent of route. Route will differ after some. Charterparties will vary after every so many years. Due to chartering, will need to install BWT. Your questionnaire is too complex. Our position

	is simply as follows: There is a desperate need to develop and implement international standards and procedures for the evaluation and approval of new ballast water treatment systems. There is a huge variation in the biological effectiveness of open sea exchange, and it is therefore extremely difficult to use it as a benchmark for comparison with other systems (this was recently confirmed at our Ballast Water Treatment R&D Symposium, Standards Workshop and MEPC 46). Any company that claims their system is as effective or more effective (or even less effective) than open sea exchange must therefore be questioned. There is a danger here that the shipping industry will end up spending large sums of money on ballast water treatment systems that do not really do anything useful in terms of killing organisms and which may become redundant as soon as IMO agrees an international standard for such systems. Until international standards and procedures for the evaluation and approval of new ballast water treatment systems are agreed and implemented any shipping company fitting or adopting alternative ballast water treatment systems should do so in full recognition of this risk. While shipping companies should be strongly encouraged to fit and test alternative systems in real-life operational situations, but it must be made clear that until these systems are proven effective and approved by a relevant jurisdiction, they experimental only. Also, your statement on the Assumption that "IMO recommends (as it currently does) that ballast water exchange or alternative treatments be undertaken regardless of the presence of port state requirements" is incorrect. Please refer to the following sections of the IMO Guidelines (A.868(20)): 3. Application The Guidelines are directed to Member States and can apply to all ships, however, a port State authority shall determine the extent to which they do apply. 4.2. The Guidelines allow port States to exempt ships within the area under their jurisdiction from part, or all of the relevant provisions. 9.2 Ballast water management options Ballast water exchange is presented as one of

	several options, not THE recommended option. As discussed there is a serious mis-conception that the IMO Guidelines are all and only about ballast exchange at sea. This is clearly not the case. Ballast exchange at sea is presented as one option in the tool box and there are many other very useful management measures recommended by the guidelines, including record keeping and reporting, ship-board ballast water management plans, regular cleaning and sediment removal, and port State activities. IMO does not recommend ballast exchange at sea regardless of the presence of port State requirements. Please refer to the full set of guidelines and do not mis-represent the IMO recommendations.

Appendix 2
Compilation report 2 expert round

Results Expert Round 1

In this document, the results of the first Expert Round Survey are presented. Below, the questions as well as a summary and the details of the answers are provided.

Assumptions (given to the respondent)

Assume that at least several port states direct ships to undertake high-seas ballast water exchange or some alternative BWT prior to entering their waters. Also assume that the IMO recommends (as it currently does) that ballast water exchange or alternative treatments be undertaken regardless of the presence of port state requirements. Also assume that some port states have stricter environmental standards for receiving waters than others. Finally, assume that candidate BWT systems are available but not yet utilized by a number of ships, and therefore, not yet "well-proven" operationally or biologically.

Questions

1. Criteria for ship owners

Question What are in your opinion the most important criteria or features for ship owners when considering purchase and installation of BWT equipment? (please sort in order of importance from top (important) to bottom (less important)(use drag / cut&paste)). Ease of on-board construction/fitting Capital Investment cost Operational cost Time needed for operation (process time) Expected life time (economic, technical) Reliability Effectiveness at reducing risk of introduction of species Availability of technical/maintenance services Convenience of operations (need for skilled staff etc.) Acceptance by port authorities Environmentally sound Chemical-free SUMMARY Most important is that technology meet regulations: it must meet the forthcoming IMO standard and must be accepted by port authorities. Second most important criterion is the cost over the lifetime of the investment. Third comes reliability and user-friendliness.	1.Reliability 1.Operational cost 1.Effectiveness at meeting required standard [reducing risk of introduction of species] 2.Time needed for operation (process time) 2. Availability of technical/maintenance services 2. Convenience of operations (need for skilled staff etc.) 3.Ease of on-board construction/fitting 3.Capital Investment cost 3.Expected life time (economic, technical) * 0.Acceptance by port authorities 0.Environmentally sound 0.Chemical-free Effectiveness at reducing risk of introduction of species/Acceptance by port authorities/Environmentally sound Reliability Operational cost/Capital Investment cost /Time needed for operation (process time)/Convenience of operations (need for skilled staff etc.) Ease of on-board construction/fitting / Availability of technical/maintenance services Expected life time (economic, technical) Most important is the acceptance by port authorities, and is linked to effectiveness and reducing risk of introduction of species. Time needed for operation Ease of onboard construction/fitting for both existing and new vessels Chemical free not necessary as long as acceptable

	Acceptance by port authorities Time needed for operation (process time) Operational cost Expected lifetime (economic, technical) Reliability Effectiveness at reducing risk of introduction of species Availability of technical/maintenance services Convenience of operations (need for skilled staff etc.) Capital Investment cost (new ships only, if retrofitting the most important item) Environmentally sound Chemical-free Ease of on-board construction/fitting (only for new ships, if retrofitting this item the second most important item**)** Acceptance by port authorities Capital Investment cost Operational cost Expected life time (economic, technical) Reliability Time needed for operation (process time) Availability of technical/maintenance services Ease of on-board construction/fitting Effectiveness at reducing risk of introduction of species Convenience of operations (need for skilled staff etc.) Environmentally sound Chemical-free
Additional remarks	

2. Who will be the fist to install BWT?

Question Which flag states? SUMMARY Wealthy nations and/or the nations with BW regulations in place.	Ship owners of wealthy nations, perhaps Norway Flags of countries with laws in place may come first, but well-managed companies of any flag could be one of the earliest to install. Scandinavian Australia, US and the EU USA, Norway, the Netherlands, Australia, UK etc. In general: Quality Flags.
Question Which types of ships? SUMMARY Cruise ships, bulk carriers, tankers,	Bulk carriers due to vulnerability to officialdom Those with smaller flow rates and/or which are visible to the public will be first: cruise ships, container ships, and oil tankers on the west coast of the US Tankers, Bulk carriers (australia a lot), Containers

containers. Least: general cargo and dedicated vessels. Low flows may make adoption of BWT easier.	Cruise ships, Bulk carriers and Tankers Oil tankers, dry bulk carriers, chemical tankers.
Question Which sizes (DWT)? SUMMARY In future all sizes.	Not realistic to guess (see above) Above 5000 M/T (in the future all sizes) More than handy size 25,000 DWT
Question Which routes? SUMMARY Particularly linked with countries that now have unilateral regulations: USA, Australia, EU countries.	Ships engaged, or offering on Australian trade, or North American trade. (see above) Linked to 14 countries with unilateral approaches Australia, US, South America and the EU Those countries which are enforcing this by law. Besides that countries with large oil and bulk trades.
Question Which age of ships? SUMMARY Primarily new ships, but cruise ships also the older ones.	Primarily, new ships Younger ships are a better investment **New ships only (except for Cruise ships)** Less than 10 years (depends also on investment requirements. Vessels are maybe allowed to be phased out. See discussion regarding Double Hull.
Question Which type of ship owners (size, nature,….)? SUMMARY Particular the larger companies, with their own environmental management systems.	Major independents, Maersk, Bergesen, P&O, Evergreen, StenaBulk, and major cruise lines. Larger Companies, ISO 14000 or similar certificated companies and Cruise operators. Larger ship owners with fleets of say 10 or more vessels.
Additional remarks	

3. New ships, retrofitting in existing ships

Question To what extent do you think ship-owners will wish to retrofit existing ships with BWT to avoid the need to undertake ballast water exchange? (open question) SUMMARY Limited potential, design is often not compatible.	Only if the cost of retrofit is very low <u>and</u> operational costs are markedly lower than exchange, <u>and</u> they have an assured trading pattern that will insist on something being done. None or very limited, this is not likely with the currently available equipment and techniques. However, the market forces and national/regional regulations could demand installations of such retrofitting. Depends largely on investment costs and the ability they can pass on the bill to their customers.
Question How do you view the potential for installing BWT in existing ships?	Very low. Very limited

Question How much will ship owners be willing to invest relative to the value of the ship?	Very low. Would indeed very most depend on the age, type and trade of the ship Depends largely on the existing costs related to the use of ballast water (fuel consumption of pumps, wear/teat equipment, hull stress etc.), but as an initial guess: 2-3%.
Question To what extent will they invest in installation on new ships?	100% if legislation is impending and systems exist. Buyers will insist on good exchange systems if no reliable BWT system exists. Would indeed very most depend on the age, type, trade of the ship and the current market situation for that ship type Certainly if countries have this enforced by law and these countries play an important role in their trading/routing patterns.
Question For which ship owners/classes are these potentialities most likely?)	Owners of ships that will trade to nations that have already signaled the intention to require ballast treatment and to monitor compliance. Cruise operators
Additional remarks	This is best answered by the ship owners themselves. In my experience, there is a desire to install on existing ships as well as new ships to avoid BWE requirements. Dependant on regulations. If required to treat, retrofit will be needed. Repressive approach of a certain country, possible convention that BWT necessary is.

Countries taking the lead

Question Which countries or regions do you expect to be pioneers in regulating BWT and/or enforcing set standards? (open question) SUMMARY Australia, USA, Brazil, Canada, perhaps Norway.	Australia, Brazil, Canada, New Zealand, USA. Norway may decide to proceed for domestic political reasons, and because they can expect the support of their own ship owners. US, Australia, New Zealand, Brazil Australia and US. (evt Canada) Australia, US and the EU USA, Norway, the Netherlands, Australia, UK etc. In general: Quality Flags.
Additional remarks	

Driving forces for ship owners

Question What will be the reasons or driving forces for ship owners to invest in, and use BWT? (please sort in order of importance from top (important) to bottom (less important)(use drag / cut&paste)) Clients ask for overall environmental soundness, ‘green label’ Want to be a ‘responsible ship owner’ Legislation requires some action, and I	1. Legislation requires some action, and I prefer BWT to ballast water exchange. 2. Encountering difficulties in ports that are currently serviced by the ship owner. 3. Clients ask for overall environmental soundness, 'green label' 3. Want to be a 'responsible ship owner' 3. Clients ask for BWT specifically 0…Access to new countries and regions 0. Do not want to be a 'sub-standard ship

prefer BWT to ballast water exchange Clients ask for BWT specifically Access to new countries and regions Do not want to be a ‘sub-standard ship owner’ Encountering difficulties in ports that are currently serviced by the ship owner SUMMARY In the first place the BW regulations ship owners have to comply with in order to gain/maintain access to a certain market. Environmental awareness and progressiveness form sometimes a secondary drive.	owner'. Legislation requires some action, and I prefer BWT to ballast water exchange/Encountering difficulties in ports that are currently serviced by the ship owner/Access to new countries and regions Clients ask for overall environmental soundness, 'green label'/Want to be a 'responsible ship owner'/Do not want to be a 'sub-standard ship owner' Clients ask for BWT specifically Legislation requires some action Access to new countries and regions Encountering difficulties in current ports. Encountering difficulties in ports that are currently serviced by the ship owner Clients ask for BWT specifically Access to new countries and regions Clients ask for overall environmental soundness, 'green label' Legislation requires some action, and I prefer BWT to ballast water exchange Want to be a 'responsible ship owner' Do not want to be a 'sub-standard ship owner' Access to new countries and regions Encountering difficulties in ports that are currently serviced by the ship owner Clients ask for BWT specifically Do not want to be a 'sub-standard ship owner' Clients ask for overall environmental soundness, 'green label' Want to be a 'responsible ship owner' Legislation requires some action, and I prefer BWT to ballast water exchange
Additional remarks	Assuming that “Access to new countries and regions” means to areas where BWT is a requirement for existing ships. The item “Do not want to be a 'sub-standard ship owner'” is misleading, this would only apply if BWT where ruled to be an international requirement for existing ships.

6. Success of BWT

BWT introduction should have realistic and preferably operational and measurable objectives for ship owners.

Question From a ship owners perspective, how would you measure the potential for success of a proposed BWT? What kind of indicators would you propose (fleet coverage, costs, availability for vessel type)? (open question) SUMMARY Reliable systems with high capacity available on the market. Emerging performance of equipment. Standards and certification a fact.	A proven capability, with certification by a respected body. The system should be based on a known technology, and be backed by a known engineering firm. Not a ship owner, but would imagine that shipboard performance and reliability at pilot scale would be the first predictive indication, then biological performance data, shipboard tests, cost estimates, and availability to a variety of vessels. By the International regulations and standards, as well to some extent the cost involved High capacity, compliance with regulations and standards, low investment and low maintenance cost Costs, trading flexibility, earning capacity
Additional remarks	Most important is flow rate. Capacity lacking.
Question When would you call an introduction of a BWT in the market place a success? (open question) SUMMARY Regulations in place and equipment being installed & used.	When it is specified by a ship owner in a new building contract, or by a Coastal State as being acceptable. When it has been approved by the IMO or a port state as meeting treatment requirements for a certain class of ships. Effective and volume friendly and acceptance by legislation **That would depend on the BWT market mechanisms (competitors and the overall shipping market in general)** **If a similar approach is taken and implementation scheme is introduced as f.i. the double hull tankers.** **Ratification of IMO member states.**
Additional remarks	

Other remarks

	Differentiation Differentiation with BWT: in risk areas, might influence acquiring BWT. Vessels Charters: in Charterparty will specify BWT needed due to route changes: so vessels will install independent of route. Route will differ after some. Charterparties will vary after every so many years. Due to chartering, will need to install BWT. Your questionnaire is too complex. Our position is simply as follows: There is a desperate need to develop and implement international standards and

	procedures for the evaluation and approval of new ballast water treatment systems. There is a huge variation in the biological effectiveness of open sea exchange, and it is therefore extremely difficult to use it as a benchmark for comparison with other systems (this was recently confirmed at our Ballast Water Treatment R&D Symposium, Standards Workshop and MEPC 46). Any company that claims their system is as effective or more effective (or even less effective) than open sea exchange must therefore be questioned. There is a danger here that the shipping industry will end up spending large sums of money on ballast water treatment systems that do not really do anything useful in terms of killing organisms and which may become redundant as soon as IMO agrees an international standard for such systems. Until international standards and procedures for the evaluation and approval of new ballast water treatment systems are agreed and implemented any shipping company fitting or adopting alternative ballast water treatment systems should do so in full recognition of this risk. While shipping companies should be strongly encouraged to fit and test alternative systems in real-life operational situations, but it must be made clear that until these systems are proven effective and approved by a relevant jurisdiction, they experimental only. Also, your statement on the Assumption that "IMO recommends (as it currently does) that ballast water exchange or alternative treatments be undertaken regardless of the presence of port state requirements" is incorrect. Please refer to the following sections of the IMO Guidelines (A.868(20)): 3. Application The Guidelines are directed to Member States and can apply to all ships, however, a port State authority shall determine the extent to which they do apply. 4.2. The Guidelines allow port States to exempt ships within the area under their jurisdiction from part, or all of the relevant provisions. 9.2 Ballast water management options Ballast water exchange is presented as one of several options, not THE recommended option. As discussed there is a serious mis-conception that the IMO Guidelines are all and only about

	ballast exchange at sea. This is clearly not the case. Ballast exchange at sea is presented as one option in the tool box and there are many other very useful management measures recommended by the guidelines, including record keeping and reporting, ship-board ballast water management plans, regular cleaning and sediment removal, and port State activities. IMO does not recommend ballast exchange at sea regardless of the presence of port State requirements. Please refer to the full set of guidelines and do not mis-represent the IMO recommendations.

Appendix 3
Ship Types in Lloyds Register

Grouped as:	**Shiptype**	**Total in World fleet**	***Not relevant ship types***	***Total in World fleet***
Bulk Carriers	Aggregates Carrier	486	*Air Cushion Vehicle*	*20*
total: 7,050	Alumina Carrier	2	*Anchor Hoy*	*47*
	Barge Carrier	29	*Buoy / Lighthouse Vessel*	*237*
	Bulk / Oil Carrier	134	*Cable-Layer*	*92*
	Bulk Carrier	4.891	*Crewboat*	*255*
	Cement Carrier	436	*Dredger*	*626*
	Fish Carrier	547	*Drilling Ship*	*54*
	Limestone Carrier	37	*Fire-Fighting Vessel*	*116*
	Ore / Oil Carrier	72	*Fish Factory Ship*	*90*
	Ore Carrier	78	*Fishing Support Vessel*	*143*
	Powder Carrier	5	*Fishing Vessel*	*13.553*
	Refined Sugar Carrier	3	*Hopper Dredger*	*513*
	Self-Discharging Bulk Carrier	170	*Hospital Vessel*	*14*
	Stone Carrier	34	*Icebreaker*	*62*
	Urea Carrier	8	*Kelp Dredger*	*1*
	Wood Chips Carrier	118	*Landing Craft*	*431*
Container Ship	Container Ship	2.648	*Launch (Unspecified)*	*70*
Crude Oil Tanker	Crude Oil Tanker	1.815	*Log-Tipping Ship*	*2*
Chemical Tanker	Chemical Tanker	1.322	*Mooring Vessel*	*52*
Chemical / Oil Products Tanker	Chemical / Oil Products Tanker	1.242	*Motor Hopper*	*485*
General Cargo Ship	General Cargo Ship	17.491	*Offshore Processing Ship*	*53*
LNG Tanker	LNG Tanker	131	*Offshore Supply Ship*	*1.370*
LPG Tanker	LPG Tanker	1.010	*Offshore Support Vessel*	*201*
Passenger (Cruise) Ship	Passenger (Cruise) Ship	358	*Offshore Tug / Supply Ship*	*1.220*
Passenger -Passenger/cargo (RoRo)	Passenger / Container Ship	3	*Other Non-Merchant Ships*	*507*
total: 2,942	Passenger / Gen. Cargo Ship	348	*Passenger Landing Craft*	*42*
	Passenger / Ro-Ro Cargo Ship	2.591	*Patrol Vessel*	*294*
Passenger Ship	Passenger Ship	2.793	*Pearl Shells Carrier*	*2*
Oil Products Tanker		5.376	*Pilot Vessel*	*115*
Refrigerated Cargo Ship	Fruit Juice Tanker	9	*Pipe-Layer*	*20*
total: 1,451	Refrigerated Cargo Ship	1.442	*Pollution Control Vessel*	*335*
Ro-Ro Cargo Ship	Ro-Ro Cargo Ship	886	*Production Testing Vessel*	*10*
total: 893	Container Ro-Ro Cargo Ship	7	*Pusher Tug*	*405*
Livestock Carrier	Livestock Carrier	123	*Sail Training Ship*	*1*
Vehicles Carrier	Vehicles Carrier	583	*Salvage Ship*	*91*

Special transport	Crane Ship	163	*Seal-Catcher*	*12*
total: 227	Heavy Load Carrier	64	*Search & Rescue Vessel*	*60*
Miscellaneous tankers	Coal / Oil Mixture Tanker	1	*Standby-Safety Vessel*	*289*
total: 338	Edible Oil Tanker	13	*Supply Vessel*	*149*
	Fish Oil Tanker	2	*Tank-Cleaning Vessel*	*7*
	Latex Tanker	1	*Tender (Unspecified)*	*38*
	Molasses Tanker	8	*Training Ship*	*98*
	Oil-Sludge Tanker	13	*Trans-Shipment Vessel*	*6*
	Vegetable Oil Tanker	25	*Trawler*	*10.350*
	Water Tanker	147	*Tug*	*9.116*
	Wine Tanker	21	*Utility Vessel*	*168*
	Bitumen Tanker	107	*Waste Disposal Vessel*	*98*
Misc vessels	Deck Cargo Ship	47	*Well-Stimulation Vessel*	*11*
total:1,098	Live-Fish Carrier	55	*Whale-Catcher*	*12*
	Naval / Naval Auxiliary	60	*Work / Repair Vessel*	*57*
	Nuclear Fuel Carrier	13	*Yacht*	*396*
	Palletised Cargo Ship	69		
	Research Vessel	854		
Subtotal:		***48.891***	***Subtotal:***	***42396***
			total in Lloyds Register	**91.287**