Global **Ballast Water**
Management Programme

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1st International Ballast Water Treatment Standards Workshop

IMO, LONDON, 28-30 MARCH 2001

Workshop Report

Steve Raaymakers

GEF UNDP IMO

A cooperative initiative of the Global Environment Facility,
United Nations Development Programme and International Maritime Organization.

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The Global Ballast Water Management Programme (GloBallast) is a cooperative initiative of the Global Environment Facility (GEF), United Nations Development Programme (UNDP) and International Maritime Organization (IMO) to assist developing countries to reduce the transfer of harmful organisms in ships' ballast water.

The GloBallast Monograph Series is published to disseminate information about and results from the programme, as part of the programme's global information clearing-house functions.

The opinions expressed in this document are not necessarily those of GEF, UNDP or IMO.

Disclaimer

This report attempts to present the overall outcomes and recommendations from the *1st International Ballast Water Treatment Standards Workshop* convened by the Programme Coordination Unit (PCU) of the Global Ballast Water Management Programme (GloBallast) at the International Maritime Organization (IMO) in London from 28 to 30 March 2001.

The report was drafted by the GloBallast PCU from each of the Workshop's Working Group reports and the results of plenary discussions, and included review of a draft version by Workshop participants.

While every attempt has been made by the GloBallast PCU to consolidate and present the various and diverse views, opinions, outcomes and recommendations of the Workshop as accurately as possible, the PCU takes no responsibility what-so-ever for any errors or omissions. The views expressed in this report are not necessarily those of the PCU, IMO or any other party or individual.

This report should be considered as a "possible options" paper only, prepared for the purposes of discussion by interested parties. It has no official status under the auspices of any particular organization.

Contents

1 Introduction & Background

The introduction of harmful aquatic organisms and pathogens to new environments, including via ships' ballast water, has been identified as one of the four greatest threats to the world's oceans. It is estimated that a foreign marine species is introduced to a new environment somewhere in the world every nine weeks. Human health, ecological and economic impacts can be severe.

The International Maritime Organization (IMO), with funding provided by the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP), has initiated the Global Ballast Water Management Programme (GloBallast).

The overall objective of the programme is to reduce the transfer of harmful marine species in ships' ballast water, by assisting developing countries to implement existing IMO voluntary *Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens* (Assembly Resolution A.868(20)). The programme is also assisting developing countries to prepare for the new international convention on ballast water currently being developed by IMO.

2 The Need for and Purpose of the Workshop

The main management measure recommended under the existing IMO ballast water guidelines is ballast water exchange at sea (including the empty/refill, flow-through or dilution methods). The three currently generally accepted methods of ballast water exchange at sea remain the best currently available methods of minimizing the transfer of harmful aquatic organisms and pathogens and the Workshop recognized it appears likely that they will remain the best available method for the foreseeable future. However, it is recognized that this approach has some limitations, including safety concerns for some vessels in certain circumstances and the fact that translocation of species may still occur even when a vessel has undertaken ballast water exchange.

It is therefore important that alternative, safer and more effective ballast water treatment (BWT) methods are developed as soon as possible. Significant research and development (R&D) efforts are underway by a number of establishments around the world, aimed at developing a more complete solution to the problem. However, one of the problems currently faced by the global R&D and shipping communities is that there are currently no internationally agreed and approved standards, and in particular *biological effectiveness standards* (*biological effectiveness* meaning removing, killing or otherwise rendering inactive aquatic organisms and pathogens found in ballast water). Such standards are required for the evaluation and approval of new and future alternative BWT systems to be developed.

Most parties involved in the ballast water issue have identified the current lack of such standards as one of the obstacles to finding a more complete alternative treatment technique to the ballast water problem. In particular, the global shipping industry has made repeated calls for international BWT standards to be developed and adopted. This will provide the industry with a clear target to aim for and encourage private sector innovation to be brought to bear on providing new alternative methods.
To help address this situation, the GloBallast Programme Coordination Unit (PCU) organised the *1st International Ballast Water Treatment Standards Workshop* from 28 to 30 March 2001.

3 Workshop Objective

To develop a range of possible standards, and in particular ***biological effectiveness standards,*** for the evaluation and approval of new BWT systems, which may be made available to MEPC 46 and other interested parties for information/consideration.

4 Workshop Structure & Format

The Workshop programme is contained in Appendix 1. The Workshop comprised 66 of the world's leading experts in the field of ballast water management and treatment, covering a broad representative base including shipping industry, governments, marine science, water treatment industry and research and development community from both developed and developing countries (a participants list is contained in Appendix 4).

The Workshop was preceded by the two day 1st International Ballast Water Treatment R&D Symposium, at which 26 technical papers were presented updating the current status of various BWT technologies around the world. The Workshop itself commenced with the presentation of nine background papers, including the perspectives of the shipping industry, a marine science perspective, an engineering perspective and several papers on various individual national activities relating to BWT standards. The preceding Symposium and the background papers (Appendix 5) presented at the Workshop itself ensured that all participants were fully briefed with the latest global information relating to BWT technology and standards.

Workshop participants were divided into six Working Groups, each facilitated by two members of the GloBallast Technical Advisory Group (Appendix 3) and comprising a cross section of marine scientists, water treatment specialists, shipping industry representatives and government officials. Each Working Group was tasked with the development of possible BWT biological effectiveness standards according to a clear set of instructions (Appendix 2). Each Working Group reported to plenary. This consolidated report was drafted by the GloBallast PCU from each Working Group's report and the results of plenary discussions, and included review of a draft version by Workshop participants.

5 Workshop Outcomes and Recommendations

The outcomes and recommendations of the Workshop may be considered as the consensus expert opinions of the world's foremost authorities in this field. The Workshop expects that its outcome and recommendation would be taken into account by MEPC as information in developing the new international ballast water convention.

The Workshop was successful in unanimously agreeing five Primary Criteria for new BWT technologies and a number of Fundamental Principles as the basis for developing biological effectiveness standards. The Workshop proposed some possible options for such a standard. The main outcomes and recommendations of the Workshop are given in sections 5.1 to 5.6 below.

5.1 New Ballast Water Treatment Technologies - Primary Criteria

The Workshop unanimously agreed and recommends that any new alternative BWT technologies should meet the five following primary criteria:

1. It must be safe (in terms of the ship and its crew).
2. It must be environmentally acceptable (not causing more or greater environmental impacts than it solves).
3. It must be practicable (compatible with ship design and operations).
4. It must be cost effective (economical).
5. It must be biologically effective (in terms of removing, killing or otherwise rendering inactive aquatic organisms and pathogens found in ballast water).

The Workshop agreed to focus on developing possible standards for biological effectiveness (Primary Criterion 5), and that these should be developed in light of the other four Primary Criteria. If specific standards are required for the other four Primary Criteria, these should be developed by other bodies comprising relevant experts.

5.2 Biological Effectiveness Standards - Fundamental Principles

In developing possible biological effectiveness standards the Workshop unanimously agreed and recommends that the following Fundamental Principles should be applied:

1. The three currently generally accepted methods of ballast water exchange at sea (empty/refill, flow-through and dilution) remain the best currently available methods of minimising the transfer of harmful aquatic organisms and pathogens. It appears likely that they will remain the best available methods for the foreseeable future.
2. While recognising point 1 above, it is not appropriate to use equivalency to ballast water exchange as an effectiveness standard for evaluating and approving/accepting *new* and future more complete ballast water treatment technologies, as the relationship between volumetric exchange and real biological effectiveness achieved by ballast water exchange is not defined. This relationship cannot be established without extremely expensive empirical testing. In this context, the lack of standards for new and alternative ballast water management technology should not be considered as an obstacle for implementation of currently available and generally accepted three methods of ballast water exchange, under the IMO Guidelines or the new legal instrument under development at MEPC.
3. The standard should be based on the concept of reducing/minimising the risk of biological introductions through ballast water, recognising that 100% biological effectiveness of ballast water treatment is not achievable for all aquatic organisms and pathogens with best currently available technology.
4. It should be a Performance Standard as opposed to a Process Standard or a Management Standard.
5. The type approval test should be based on water quality.
6. A single, global, uniform, primary biological effectiveness standard should be developed, although it may be appropriate to develop additional standards for specific situations (e.g. different geographical regions, different taxonomic groups, different vessels), based on a risk assessment approach.
7. Flexibility must be retained to allow the standard(s) to be revised and updated over time as technology develops, knowledge increases and improved ballast water treatment biological effectiveness becomes possible.
8. It would be useful for relevant bodies to develop a list of global species of concern, to aid in refining such standards.

9. It may be appropriate in certain circumstances to use surrogate measurements in evaluating ballast water treatment effectiveness, but these should be calibrated against actual organisms.
10. The applicability of the standard(s) to new versus existing ships needs to be resolved.

5.3 Biological Effectiveness Standards – Proposed Options

Considering the Primary Criteria and Fundamental Principles outlined above, the Workshop proposed and recommends that the following two main options be considered as possible international BWT biological effectiveness standard(s); for use in evaluating and approving/accepting *new* BWT systems that may be developed as alternatives to ballast water exchange at sea.
It should be noted that Option One represents a consolidation of the recommendations of five of the six Working Groups while only one Working Group recommended Option Two. Option Two is presented here for the sake of completeness.

5.3.1 Option One: 95% Removal/Kill/Inactivation Relative to Defined Standard Intake

Proposed standard:

(text in square brackets [ ] indicates gaps/more contentious issues)

1 In order to be approved/accepted any new ballast water treatment technology must:

achieve at least 95% removal, kill or inactivation of a representative species from each of five representative taxonomic groups(specified in Appendix X) in ballast water discharged overboard, relative to intake for a defined set of standard biological, physical and chemical intake conditions (specified in Appendix Y);

report data on removal, kill or inactivation of pathogens, dinoflagellate cysts and similar organisms of concern.

2 For pathogens, dinoflagellate cysts and similar organisms of concern a Port State may require a higher level of treatment than that specified in the international standard under 1 above [for example 99.9999% removal, kill or inactivation] [but in doing so must meet any costs imposed over and above those required for a ship to meet the international standard*].

Appendix X: Representative taxonomic groups

Vertebrates, invertebrates, (hard-shelled, soft shelled, soft-bodied), phytoplankton, macro-algae

[to be developed further]

Appendix Y: Defined standard biological and physical/chemical intake conditions

Biological:

[For each representative species the highest expected natural concentration of organisms in the world as derived from available literature?] [to be developed further].

Physical/chemical: [values for each to be developed]

Salinity, turbidity, temperature, pH, dissolved oxygen, particulate organic matter, dissolved organic matter.

* Some parties suggested this so as to allow Port States to set higher standards for particular species of concern to them, without imposing costs on the shipping industry over and above those required to comply with the basic international standard of at least 95%. To do otherwise would negate the entire value of having an international standard. Significant practical impediments to this approach were identified by other parties.

5.3.2 Option Two: 100% Removal/Kill/Inactivation of all Organisms > Size Classes

Proposed standard:

(text in square brackets [ ] indicates gaps/more contentious issues)

In order to be approved/accepted any new ballast water treatment technology must achieve:

1 *near 100% removal, kill or inactivation of all organisms:*
- *larger than 100 microns in size by* [2003/2005?].
- *larger than 50 microns in size by* [2007/2010?].

2 *near 100% removal, kill or inactivation of organisms larger than 10 microns in size of particular concern to certain Port States* [by year???].

5.4 Rationale Behind the Proposed Standards - Explanatory Notes

5.4.1 Option One: 95% Removal/Kill/Inactivation Relative to Defined Standard Intake

- This proposed standard adopts "at least 95%" in recognition that best currently available technology is unable to achieve 100% removal, kill or inactivation of all organisms and pathogens carried in ballast water. The workshop considered that 95% is a practical and realistic initial target for which to aim and from which to work. It is consistent with the risk reduction/minimisation approach agreed as a Fundamental Principle for the development of these standards.

- It should be noted that 95% (or any percentage) is only meaningful if measured against an initial value. For the purpose of this standard the initial value might be the highest expected natural concentration of organisms in the world for each representative species as derived from available literature. This standard definition on intake concentration is necessary as it is entirely impractical to measure concentrations of organisms in the ballast water every time a vessel takes on ballast water.

- It should be noted that definition of representative taxonomic groups and standard intake conditions is a major task requiring significant effort and further meetings of relevant groups of experts. However, once these are defined a water quality performance standard will be arrived at for the discharge. This will provide industry with certainty and clarity and allow innovation in complying with the standard.

- It should be noted that the use of 95% in Option One in no way relates to the 95% volumetric exchange of ballast water theoretically achievable in flow-through ballast water exchange at sea. The latter is not a measure of biological effectiveness and the workshop agreed that it is not appropriate to use equivalency with volumetric exchange as a biological effectiveness standard.

- Option One requires that the standard be met in relation to ballast water discharge, in recognition of the fact that should the standard be met at time of intake, organisms may subsequently multiply in the ship's ballast tanks during the voyage resulting in a discharge in excess of the standard.

- Option One uses representative species from five representative taxonomic groups as a 'mandatory achievement' in recognition of the fact that it is entirely impractical to evaluate biological effectiveness for the full range of organisms carried in ballast water.

- Option One excludes pathogens, dinoflagellate cysts and similar organisms of concern from the representative groups and accords them separate treatment as a 'reporting achievement', in recognition of the fact that at least 95% removal, kill or inactivation of these species will be extremely difficult to achieve with best currently available technology. The 'reporting achievement' approach for these 'difficult' species provides that initially vendors of new ballast water treatment technologies will report data on removal, kill or inactivation of these species, allowing the standard to be revised and updated as data accumulates and technology improves over time.

5.4.2 Option Two: 100% Removal/Kill/Inactivation of all Organisms > Certain Size Classes

- This proposed standard is based on a recognition that while there are many species of significant concern below 100 microns in size that may be transferred in ballast water, it is highly desirable to start with a target that may be achievable with best currently available technology, followed by a staged development towards more stringent targets of 50 and eventually 10 microns.

- Considering the risk reduction/minimisation principle agreed by the workshop, such a standard would allow practical measures to be taken to reduce/minimise risks of many introductions while further research and development is undertaken to allow the standards to be further refined to address a broader range of organisms more effectively over time.

- This option is limited by the fact that many species and even life-stages within species span the 100 micron and even the 50 micron dimension, and 100% > 100 microns may be less effective than the 'at least 95%' approach under Option One.

- Option Two may also narrow the field of technical options that might be used. However, the Working Group which put forward this option argued that although best currently available technology is not able to effectively remove, kill or inactivate all aquatic organisms and pathogens in ballast water, this should not be used as a reason for not addressing at least those species than can be removed, killed or inactivated.

5.5 Other Issues Raised in Relation to Standards

A number of additional points and views were presented during the Workshop, including the following:

- Further discussion is required on the taxonomic groups that should be targeted and the percentage removal that might be achieved. However, it was broadly agreed that a "starting point" must be established from which to move forward.

- A higher (more stringent) standard might be developed for 'more motivated' ships and different tiers or levels of standards could be applied with 'minimum mandatory' and 'incentive-rewarded' categories.

- There was some discussion regarding the current state of scientific knowledge and how gaps in this knowledge affect the ability to set standards. It was generally agreed that lack of full knowledge should not be used as a reason for not setting a starting point that could begin to reduce risks now, while allowing for the standards to be developed further through an iterative process as research and development continues.

5.6 Effectiveness Evaluation/Compliance Monitoring

The Workshop agreed that:

- Performance testing of BWT equipment against the standard should be carried out in the laboratory and on ships according to standardised international procedures. Equipment types that achieve the standard should be certified for ship-board installation. Limited verification testing that the equipment is achieving the standard in real-life applied conditions should be carried out on a ‘spot-check’ basis.

- A group of relevant experts should be assembled under the auspices of the MEPC Ballast Water Working Group to develop standardised international procedures for effectiveness evaluation/compliance monitoring.
- Administrative, procedural and technical arrangements will need to be developed for the evaluation and acceptance/approval/certification and monitoring of new alternative BWT systems against the international standard.

Appendix 1:
Workshop Programme

Tuesday 27 March 2001

1930-2100: Pre-Workshop briefing and instructions to core Technical Advisory Group, Meeting Room 1, 2nd Floor, IMO.

Wednesday 28 March 2001: Day 1

0830-0900: Registration (at Registration Desk, 1st floor, IMO)

All workshop sessions will be held in Meeting Room One, 2nd floor, IMO.

Opening & Introduction

Chairman: Mr Koji Sekimizu, Director, IMO Marine Environment Division

0900-0930: Keynote Address: *Mr Denis Paterson, Founding Chairman, IMO MEPC Ballast Water Working Group*

0930-1000: The Need for BWT Standards – A Shipowners Perspective: *Mr Claudio Conclaves Land, PetroBras, Brasil.*

1000-1030: Introduction, Objectives and Structure of the Workshop: *Mr Steve Raaymakers, GloBallast PCU*

1030-1100: Tea/coffee

Session One: Scene-Setting Papers

(each presentation 20-25 min + 5-10 min questions)

Chairman: Mr Denis Paterson, Founding Chairman, IMO MEPC Ballast Water Working Group

1100-1130: Ballast Water Treatment – is 99% Effectiveness Sufficient? *A/Prof. Gustaaf Hallegraeff, Univ. of Tasmania*

1130-1200: Ballast Water Treatment Standards – a Marine Science Perspective: *Ms Allegra Cangelosi, NE/MW Inst.*

1200-1230: Ballast Water Treatment Standards – an Engineering Perspective: *Dr Thomas Waite, Univ. of Miami*

1230-1330: Lunch

Session Two: Some National Positions/Activities

(each presentation 20-25 min + 5-10 min questions)

Chairman: Mr Dandu Pughiuc, Chief Technical Adviser, GloBallast PCU

1330-1400: Possible BWT Standards –IWACO Paper: *Mr Frans Tjallingii, IWACO*

1400-1430: Possible BWT Standards – German Proposal: *Dr Matthias Voigt, Dr Voigt Consulting*

1430-1500: Possible BWT Standards – Norwegian Proposal: *Mr Aage Bjørn Andersen, DNV*

1500-1530: Possible BWT Standards – USCG Activities: *Dr Richard Everett, USCG*

1530-1600: Tea/coffee

Session Three: Working Groups

Chairman: Mr Steve Raaymakers, Technical Adviser, GloBallast PCU

1600-1630: Form Working Group. Instructions to Working Groups
(Note. Each Working Group to comprise cross section of marine science, water treatment and shipping industry representatives, headed/facilitated by a member of the GloBallast Technical Advisory Group. Each Working Group will be tasked to work towards the development of possible BWT standards.

1630-1800:Working Groups convene to commence 'brainstorming' of possible BWT standards

1800: Close day one (groups may elect to continue working)

Thursday 29 March 2001: Day 2

0845-0900: Housekeeping

Working Groups Continue

Flexibility will be retained and the programme may be changed to reflect progress

Chairman: Mr Denis Paterson, Founding Chairman, IMO MEPC Ballast Water Working Group

0900-1030: Working Groups continue

1030-1100: Tea/coffee

1100-1230: Working Groups continue

1230-1330: Lunch

Working Group Progress Reports

1330-1500: Working Groups provide Progress Reports to whole Workshop Plenary

1500-1530: Tea/coffee

1530-1800: Working Groups continue (restructure if necessary, according to Progress Report outcomes)

1800: Close day two

1830: Social Activity

Friday 30 March 2001: Day 3

0845-0900: Housekeeping

Working Group Reports

Chairman :Mr Steve Raaymakers, Technical Adviser, GloBallast PCU

0900-1030: Working Groups report on outcomes of day two to whole Workshop Plenary

1030-1100: Tea/coffee

General Discussion

1100-1230: General discussion of all Working Group proposals

1230-1330: Lunch

Compilation of Draft Report

1330-1530: Compile all Working Group proposals into outline of draft report.

1530-1600: Tea/coffee

1600-1800: Finalise outline of draft report

1800: Close Workshop

Appendix 2:
Working Group Instructions

(Flexibility will be retained and the structure may be changed to reflect progress)

1 Workshop Objective

To develop a range of possible standards, and in particular ***effectiveness standards,*** for the evaluation and approval of new BWT systems, which may be made available to MEPC 46 for information/consideration.

2 Working Group Composition

Each Working Group will be lead by a member of the GloBallast Technical Advisory Group (Attachment Two) and will comprise workshop participants who are technical experts from the shipping industry, water treatment industry, marine science community and government (Attachment Three).

3 Tasks

Each Working Group is requested to undertake the following tasks.

- Read the Background Considerations under (4) below.
- Brainstorm the development of proposed BWT effectiveness standards according to each sub-heading under (5) below.
- Nominate a rapporteur to record and report on the recommendations arising from the Working Group's deliberations. This report should be structured according to each sub-heading under (5) below, and should be submitted to the GloBallast PCU on computer disc at the end of the Working Group sessions for amalgamation into the overall Workshop Report.

In undertaking these tasks Working Group members should consider the points made during the Scene-Setting and National Position papers presented during the first part of the workshop.

4 Background Considerations

Primary Criteria

It is generally accepted that any new BWT system should meet the five following Primary Criteria.

- Safety
- Environmental Acceptability
- Practicability
- Cost Effectiveness
- Effectiveness (Efficacy)

The workshop will address each of these Primary Criteria as follows:

1. Safety

The workshop should proceed on the basis that safety is the highest priority and any proposed new BWT system must not compromise the safety of the ship and its crew.

However, it is ***not*** intended that the workshop will consider possible safety standards for new BWT systems. This is best left to other forums, such the IMO Maritime Safety Committee, in conjunction with MEPC.

2. Environmental Acceptability

The workshop should proceed on the basis that any proposed new BWT systems must be environmentally acceptable and should not cause more or greater environmental problems than they solve.

However, given the wide-range of environmental protection criteria already in existence around the world, it would be extremely difficult for this workshop to propose specific standards for the environmental acceptability of new ballast water treatment systems. It is ***not*** intended that the workshop will consider this further.

3. Practicability

The workshop should proceed on the basis that any proposed new BWT system must be practical and compatible with ship design and operational constraints.

The task of assessing the practicability of new BW treatment systems is beyond the scope of the workshop. This will to a large extent be determined by the shipping industry as part of the ship design, building and refitting process. It is ***not*** intended that the workshop will consider this further.

4. Cost-effectiveness

The workshop should proceed on the basis that any proposed new BWT system must be cost-effective and should not impose additional costs on shipping that may threaten its economic viability as an essential industry.

It is ***not*** intended that the workshop will consider specific cost-effectiveness standards for new BWT systems. The market will determine this.

5. Effectiveness (Efficacy)

While it is generally accepted that any new BWT system must be effective, in terms of killing/neutralising/removing organisms, one of the biggest barriers to finding a solution to the ballast water problem is the current lack of ***effectiveness standards***.

The development of such standards ***is the primary objective*** of the workshop. The Working Groups will be allocated various topics and tasks to achieve this objective as outlined below.

5 Development of BWT Effectiveness Standards

In developing possible BWT effectiveness standards, there are a number of issues that need to be considered, as follows:

Type of Standard

It is widely recognised in the 'world of standards' that there are two main types of standards, Management System Standards and Technical Standards. The former give overall guidance on how to develop and implement a management system in order to comply with certain requirements, and does not specifically relate to BWT effectiveness. Technical Standards in turn can be divided into Process Standards or Performance Standards.

In terms of BWT effectiveness, a Process Standard might prescribe the BWT equipment, process or system and how to operate it. It provides certainty and clarity but may not allow for flexibility and innovation. A Performance Standard would stipulate the specific requirement for the output of the BWT system. How this performance is achieved may be left to innovation.

The Working Group should consider and make recommendations on:

- Whether BWT effectiveness standards should be based on Process Standards or Performance Standards.
- What factors need to be developed further to progress this approach.

Risk Assessment/Risk Management Approach

The ultimate, ideal aim is to ensure that all discharged ballast water is totally free of harmful aquatic organisms and pathogens. This implies that a 100% effectiveness standard is required for all species carried in ballast water.

However, it must be recognised that best available technology may not be able to achieve such a standard for the huge range of species carried in a ballast water under the wide range of pertinent conditions and given the first four Primary Criteria that must be met, as outlined above.

It is therefore necessary to consider adopting a risk minimisation/risk management approach in terms of setting BWT effectiveness standards, which in practical terms may need to be less than 100%. Such an approach is routinely applied to various standards relating to the protection of human health and life (e.g. drinking water standards). Its acceptability/applicability to BWT effectiveness standards requires thorough consideration.

The Working Group should consider and make recommendations on:

- Whether it is appropriate to use a risk minimisation/risk management approach in terms of setting BWT effectiveness standards.
- If so, what factors need to be developed further to progress this approach.

Equivalency

As ballast exchange at sea is currently the only generally accepted ballast water management method, it is often used as the benchmark or de-facto effectiveness standard against which alternative ballast water management or treatment methods are assessed.

The problem with this approach is that the biological effectiveness of ballast exchange has not been determined and appears to be extremely difficult to determine. While a certain ship on a particular voyage may be able to achieve 95% volumetric exchange of its ballast water, this does not necessarily mean that all ships on all voyages can achieve it. Even when they can, it does not necessarily equate to 95% removal, mortality or neutralisation of organisms within the ballast tanks.

The Working Group should consider and make recommendations on:

- How the effectiveness of ballast exchange at sea can be more clearly defined and what further work needs to be done to achieve this?
- Whether it is appropriate to use 'equivalency' to ballast exchange as an effectiveness standard for evaluating and approving alternative BWT systems?
- How a 'volumetric exchange' standard might be compared with an 'organism removal/kill/neutralisation standard'?

Global versus Regional or Species-Specific Standards

It is possible that different countries may be concerned about different organisms in ballast water, which may require different BWT effectiveness standards. For example Australia my be concerned more about toxic dinoflaggellates than other species while the North American Great Lakes may be more concerned about zebra mussels.

The Working Group should consider and make recommendations on:

- The development of a matrix of global and regional 'species of concern'.
- Whether a single BWT effectiveness standard will cover all of these species or whether more than one standard might be required.
- Whether BWT effectiveness standards could be developed for target or representative species, and what these might be.

Surrogate Measurements

Some parties have proposed using surrogate measurements (e.g. use of synthetic microspheres to simulate plankton) in evaluating the effectiveness of mechanical BWT systems.

The Working Group should consider and make recommendations on:

- Whether it is appropriate to use surrogate measurements in evaluating the effectiveness of mechanical BWT systems.
- If so, what these surrogate measurements might be and what factors need to be developed further to progress this approach.

The Nature of the BWT Effectiveness Standard

There are currently a number of approaches that are being considered for the formulation of BWT effectiveness standards. These are:

- Percent removal of target species
- Efficiency profiling across biotic classes using indicator organisms
- Absolute concentrations of organisms in the discharge
- Mechanical/operational indicators
- Others

The Working Group should consider and make recommendations on:

- Each of the above approaches in turn and what factors need to be developed further to progress each approach.
- How strict the effectiveness standard should be, considering all previous points above.

Effectiveness Evaluation /Compliance Monitoring

Once a BWT effectiveness standard is set, technical methods need to be developed for evaluating the performance of a particular BWT treatment system against the standard and for monitoring compliance with the standard.

The Working Group should consider and make recommendations on this matter, considering its findings and recommendations on the previous matters above.

Other Matters

There is a range of other issues that need to be explored and developed in relation to BWT effectiveness standards. E.g.:

- Whether the standards should be different for existing and new ships.
- How often the standards are revised.
- The most appropriate approval or certifying body for new BWT systems (e.g. IMO, ISO, Classification Societies, National Administrations).
- The legal and administrative process for the evaluation, approval and certification of new BWT systems.

These are considered to be questions that are more in the realm of the MEPC Ballast Water Working Group than this technical Workshop. Working Groups are requested to only consider and make recommendations on these and any other matters after the higher priority technical issues under (i) to (vii) above have been addressed as fully as possible.

Appendix 3:
GloBallast Technical Advisory Group

First Name	Surname	Entity	Professional Area
Alec	Bilney	International Chamber of Shipping (ICS)	Shipping Industry
Allegra	Cangelosi	Northeast/Midwest Institute	Marine Science
Iain	Chadwick	Oil Companies Int'l Marine Forum (OCIMF)	Shipping Industry
Stephan	Gollasch	Institut fuer Meereskunde	Marine Science
Gustaaf	Hallegraeff	University of Tasmania	Marine Science
Mike	Hunter	UK Maritime and Coast Guard Agency	Government
Cláudio Gonçalves	Land	Petróleo Brasileiro SA (PETROBRAS)	Shipping Industry
Jose	Matheickal	Singapore Environmental Technology Institute	Water Treatment
Douglas	Mountfort	Cawthron Institute	Marine Science
Denis	Paterson	Denis Paterson & Associates	Consultant
Geoff	Rigby	Reninna Pty Limited	Consultant
Alan	Taylor	Alan H Taylor & Associates Pty Ltd	Consultant
Frans	Tjallingii	IWACO	Consultant
Matthias	Voigt	Dr. Voigt-Consulting	Consultant
Thomas	Waite	University of Miami	Water Treatment
Tim	Wilkins	Int'l Association of Independent Tanker Owners	Shipping Industry
Peilin	Zhou	University of Newcastle upon Tyne	Water Treatment

This Technical Advisory Group was assembled by the GloBallast PCU in order to provide a core of international recognized expertise that would guide the Workshop.

Together with the other Workshop participants (full list in Appendix 4), the Workshop brought together 66 of the world's leading experts in the field of ballast water management and treatment, covering a broad representative base including shipping industry, governments, marine science, water treatment industry and research and development community from both developed and developing countries.

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Appendix 5: Background Papers

In order as presented to the Workshop[1]

[1] Papers are published as submitted by the authors and neither the GloBallast PCU nor IMO accepts any responsibility for the content of these papers.

Standards - An Essential Ingredient for Effective Worldwide Ballast Water Management

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Introduction and Background

'Tell us what you want – then we may have some chance of complying with it.'

This has been a common, and perfectly reasonable, cry from many stakeholders in the so-called ballast water issue, for several years.

- The shipping industry wants to know so it can take the requirements into account in designing, building and operating its ships.
- Port authorities want agreed standards so that they can better manage their ports both to facilitate shipping and minimize the risk of harmful aquatic organisms entering and establishing in their ports.
- Seafood producers want standards introduced to prevent the contamination of seafood stocks, for example by toxic dinoflagillates; and to prevent the destruction of stocks, for example scallop stocks wiped out by invasions of the Northern Pacific Seastar.
- The public and environmental groups want standards to protect human health and the marine environment from marine invaders.
- Inventors and investors want standards established so they can get on with endeavoring to find new and better treatment technologies that will meet the required standards.
- Governments generally, especially of coastal states, want agreed standards both to help protect human health and the marine environment, and to assist them in putting in place appropriate management measures.
- And, last but by no means least, IMO wants agreed standards so it can fulfill its role of protecting the marine environment; which it will be better able to do with an agreed international Convention. However, such a Convention will only be possible if appropriate standards are agreed and included in it.

But before we launch off any further into this subject of developing standards, lets take a quick check on where we are at that makes their development at this point in time, so critical.

As it is now 28 years since the issue of the role of shipping in the spread of harmful aquatic organisms and pathogens (the so-called 'ballast water problem') was formally drawn to the attention of the International Maritime Organisation (IMO), it could be argued, albeit unreasonably in my opinion, that the problem should have been resolved by now; but it hasn't.

Indeed, the situation is worsening with an estimated 10 billion tonnes of ballast water being carried around the globe each year resulting in, on average, more than 3,000 species of plants and animals being transshipped daily throughout the world in ships' ballast tanks. Very little of this ballast water is being managed in a way that minimizes the spread of these marine invaders and new invasions are being recorded at an alarming rate. These are costing the world millions, perhaps billions, of dollars annually.

Furthermore, we now know that unlike other marine pollutants, such as oil spills, which can be cleaned up, the effects of marine invaders are almost always irreversible. They are one of, if not the greatest, threats to the marine environment.

However, now after several years of work, the IMO through its Marine Environment Protection Committee (MEPC), has produced a good draft of a proposed international regulatory arrangement (a Convention) for ballast water management, which will considerably alleviate the problem if correctly applied worldwide. But the draft Convention cannot be completed without the inclusion of essential standards and criteria. Indeed, as we can see [refer 'overhead'], the draft Convention presently has gaps for incorporation of these standards.

If the key stakeholders and associated experts, are not able to agree on such standards, including their evaluation, approval, operation, management and review as well as providing for and encouraging future improvements, then the IMO will not be able to move from its present advisory guidelines for ballast water management to a truly international regulatory arrangement, and **REAL** international headway, including the continuing search for more satisfactory solutions than those we presently have, will be seriously threatened.

The consequences of this occurring are serious for the world's marine environment, as well as the standard of living, public health and national prosperity in many countries, as more of the world's waterways are increasingly invaded by harmful aquatic organisms and pathogens.

Of equally serious concern is the increasing level of unilateral action by countries in an effort to stem the tide of marine invaders. Such action, while no doubt well intentioned, is resulting in inconsistencies, duplication and often questionable practicality. As the editor of the Globallast Ballast Water News said in the latest edition :

"The prerogative of coastal states to protect their coastal and marine resources from shipping impacts must be maintained. However, a piece-meal, disjointed approach is counter-productive when dealing with a transboundary, global industry such as shipping. The vital need for a uniform and effective international law on ballast water could not be greater than it is right now."

So! We need standards and we need them now. We are here to workshop the issue with the clear intention of, as a minimum producing a set of standards for ballast water treatment systems, hopefully including their evaluation, approval, application and change where necessary.

Key factors in standard-setting

So, where do we start?

I believe that there are a number of key factors that we need to have foremost in our minds in carrying out this task.

Indeed I believe that we need a set of criteria, or a template if you like, against which we can 'test' all standards that we think should apply.

Let me explain why I believe we need this template.

Firstly, it is very important that we take a pragmatic and flexible approach that not only can accommodate future developments, but indeed encourages them. Ultimately, the aim is to ensure that all discharged ballast water is totally free of harmful organisms and pathogens. That is, that those present on uptake are removed, killed or otherwise rendered harmless. However, in terms of current technology we must recognize that at this point in time there is no 'total' solution and all the procedures and practices we put in place are aimed at minimizing the risk to the extent possible.

Further essential attributes of any standards will be that they meet the now generally accepted criteria for effective ballast water management to minimize the spread of harmful aquatic organisms and pathogens as embodied in the IMO's Guidelines. These are that they be safe, practical and technically achievable, cost effective and environmentally acceptable.

Another important aspect of any standards will be that while setting a minimum level that is achievable with existing technologies and practices, they must provide a mechanism for evaluation and acceptance of future technologies and/or practices that are equivalent to, or better than, the initially agreed measures.

Any standard must, of course, not only be capable of being applied but also monitored in order that appropriate stakeholders can satisfy themselves that the required action has really been undertaken. For example, that where appropriate, ballast water has been exchanged in the required manner.

Even when each of these key factors have been satisfied there are two other very important elements that if not present, will result in the system falling into disrepute.

Firstly, the standards must be generally agreed by all key stakeholders. Unless this is the case then it is unlikely they will either be properly understood or complied with. Secondly, all standards and the means of meeting them, must be properly understood by those expected to comply with them.

In summary then, I suggest that all standards need, as a minimum, to meet the following twelve criteria:

1) Consistent with objectives of agreed IMO Guidelines.

- Just as the IMO Guidelines have been the starting point for development of the proposed new international regulatory arrangements, they should be the starting point for development of the standards and criteria that are essential if the proposed new IMO arrangements are to be achieved.
- Whilst consistency with the IMO Guidelines is necessary, provision must be made for the inevitable and very necessary future technological and operational developments – I will refer further to these two issues shortly.
- They must encourage 'best management practices' for uptake and discharge of ballast water and sediments.

2) Flexible

- Be able to accommodate both existing and future operational arrangements and technologies.
- Provide suitable, practical alternatives where appropriate; especially for ships masters.

3) Promote safe practices

- This is the pre-eminent criteria and the most essential component of all systems and arrangements relating to vessels.
- While this criteria relates primarily to ships, it is also equally relevant to all other practices and procedures, such as treatment and sampling.

4) Practical and technically achievable

- All standards whether for treatment technologies or operational arrangements, must be realistic and capable of ready and simple application.
- The technology or process must achieve the objective set for it.

5) Cost effective

- A difficult to define criteria but, never-the-less, an important one.
- In the first instance, it necessitates that all technologies or operational arrangements be costed and considered with stakeholders, especially those that will bear the cost.

6) Environmentally acceptable

- As essential as the 'safety' criteria.
- No practice must be allowed to, in any way, result in an overall increased threat to the marine or terrestrial environments.

7) Encourage new technologies and approaches

- It is generally accepted that almost all ballast water treatment technologies currently being employed, are not 'total solutions' but rather risk minimization measures.
- As we heard earlier this week, a range of new or emerging technologies such as UV, microfiltration, heat treatment, biocide/chemical treatment are under active evaluation and R&D of these, and others, must be encouraged in the interests of reaching a more satisfactory long-term solution.

8) Apply the test of equivalence

- This criteria is closely related to the earlier ones of 'flexibility' and 'encouraging new technologies'.
- Once a standard is established all stakeholders will inevitably continue the search for more suitable practices. The test of acceptance for these should be that they are, either singly or when used in conjunction with other arrangements, at least equivalent to approved/agreed arrangements in delivering the required outcome.

9) Capable of being compliance monitored

- Any technology or operational procedure employed to minimize the risk of 'marine invaders' must be capable of being monitored for compliance.
- Proposed compliance monitoring arrangements should be an essential component of any proposed international operational arrangement; if its performance cannot be measured, it should not become an 'acceptable system'.

10) Maritime and regulatory awareness

- The requirements of any agreed standards or operational arrangements must be fully and appropriately disseminated to all stakeholders.
- We can only expect compliance if requirements are received in a timely manner and are fully understood.

11) Evaluating/approving authority (ies)

- There must be agreed authorities to evaluate, approve, review etc any proposed technology or arrangement.
- Such authorities may be an existing specialist or one-off group of experts capable of carrying out an assessment, such as GESAMP, or perhaps a 'Technical Advisory Group on Ballast Water Management', which would advise IMO.

12) Agreement of all stakeholders

- To date, wide implementation of the IMO Guidelines and specific country requirements, has been achieved through mutual cooperation of all stakeholders.
- Any set of mandatory standards or criteria need the broad agreement of all key stakeholders if they are to be effective.

What standards are required?

While our task at this Workshop is to work up standards relating to treatment systems – their evaluation, approval, application – there are many other areas associated with the ballast water and invasive marine species issue, where standards will need to be set. Areas such as standards for port surveying; standards for sampling and testing; standards for compliance etc etc.

However, I suggest that, firstly, all these flow on from the treatment system standards; and secondly, the 12 point criteria I have just proposed should also apply to these other standards.

Treatment standards

A few thoughts on standards for treatment systems.

Concerning the systems themselves, the key point is to initially set a standard that will provide for acceptance of the current generally agreed operational systems or any other system that is at least equivalent. The three currently practiced ballast exchange systems of “empty and refill”; “flow-through (3 tank volumes) exchange”; and the “dilution method” are proven risk minimization approaches; two achieving greater than 95% volumetric exchange of ballast water and the other – the “dilution method” achieving 90%, and are the best we have at the moment.

A key factor in standard-setting in this area is the BASIS OF THE STANDARD. By this I mean whether the standard should be TECHNOLOGY BASED OR WATER QUALITY BASED, or possibly a combination of the two.

I suggest that the focus needs to be on WATER QUALITY. That is, what is in the discharged water? However in focusing on WATER QUALITY we will, of course, de facto, be recognizing, or approving certain technologies. For example, if we set the standard at 95% ballast water volumetrically exchanged, then we are in effect approving the “empty/refill” and “flow through” exchange methods. If we set it at 90%, we also include the “dilution method”.

The efficiency of removing organisms as distinct from removing ballast water, is a very complex issue affected by issues such as the organisms themselves, the ballast tanks, salinity of the water, temperature, sediments etc.

I suggest that we need a lot more R&D in this area before we can be definitive about it. This is another reason, I suggest, why we should at this stage set a standard based on VOLUMETRIC EXCHANGE of ballast water. Of course under our proposed equivalency provisions, any other system that produced an equivalent result would also be acceptable.

On the other hand, I believe that we should aim in the longer term to move to standards based on the level of inactivation of organisms.

Summary

In summary then, the development of acceptable international regulatory arrangements for ships’ ballast water to minimize the spread of harmful aquatic organisms and pathogens, is at a critical point.

The IMO, through MEPC and its members, has now reached an advanced stage of drafting a suitable Convention. But its completion as a credible document that has a reasonable chance of international acceptance and subsequent implementation, is dependent on the development of suitable standards, procedures and criteria.

The responsibility for the development of the standards must rest principally with the key stakeholders.

However, in developing and agreeing such standards it must be recognized that not only is this a complex issue both technologically and scientifically, but our armory of weapons is presently somewhat limited. We must therefore set our standards at a realistic level; one which we can achieve now – and which of course will reduce the risk. We must also put in place a mechanism to not only enable new systems to be evaluated and approved, but a system which encourages the progressive raising of the standards.

I first came to the IMO twelve years ago now, to inform MEPC of the seriousness of the invasive marine species issue and seek their support in doing something about it. This issue was for IMO and MEPC a totally new one for it wasn't seen as pollution of the oceans in the same way as oil, sewerage, garbage etc which was at that time the IMO's focus.

To their credit however, MEPC agreed to let us look at this issue further. At that first meeting we got six interested delegates and were allowed to meet informally after normal MEPC operating hours. Now, just twelve years later, we have got to the point of not only widespread, but indeed worldwide, recognition that invasive marine species in ships' ballast water is potentially a more serious issue than oil pollution and one of the greatest environmental challenges facing the shipping and associated industries.

We have IMO commitment to a new Convention to manage this issue worldwide. So we have come a long way in what really is a short period of time for comprehensive international action. While there are a few further steps to be taken before our objective can be realised, they are all dependent on the establishment of appropriate standards.

I hope you will join me with the GloBallast team over the next three days, to ensure that we fill this void.

Is a 99% Effective Ballast Water Treatment Sufficient?

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Introduction

In the late 1980s the classification by AQIS (Australian Quarantine & Inspection Service) of ship ballast water as a "significant quarantine issue" allowed us to commence addressing the problem. The prevalent view was that "not doing anything was no longer acceptable" and any reduction of the risk would be a worthwhile achievement. More than 10 years later, we now have reached the stage where we start to quantitatively examine the ability of different ballast water management and control options to kill or remove target species in a cost- effective manner.

The MEPC 45/2 (July 2000) discussion paper thus recommends as acceptable a ballast water control achieving "greater than 95% volumetric exchange of a ship's ballast water". Such quantitative statements now formally have raised the question of what constitutes *minimum viable populations* for selected marine pest species?

Dinoflagellate cysts

My own interest in the ballast water issue has been triggered by an apparent global increase of toxic dinoflagellate blooms impacting on aquaculture, human health and the environment (Hallegraeff 1993). The production of resistant cysts by some of these species (notably *Alexandrium catenella/ tamarense, Gymnodinium catenatum*) comprise an outstanding survival strategy and dispersal mechanism, and admittedly this has biased my view on the limitations of different ballast water treatment technologies (Hallegraeff 1998). A typical *Alexandrium* toxic plankton bloom reaches cell densities of 10^5 cells/L, of which 40% can successfully produce cysts (i.e.resulting in. 40,000 cysts/L). Assuming a cargo vessel taking on 60,000 tonnes of ballast water in such bloom conditions, a single ship thus could theoretically carry up to $2.4 .10^{12}$ cysts/L. This compares with an actual estimate of 3.10^6 *Alexandrium* cysts contained in a 25,000 tonnes woodchip carrier entering the Australian port of Eden after ballasting during a confirmed *Alexandrium* dinoflagellate bloom in the Japanese port of Muroran (Hallegraeff & Bolch 1990). In a strict sense a single viable dinoflagellate cyst would constitute a viable inoculum, but taking into account limited losses from cysts germinating under unfavourable water conditions, 1000 cysts would pose an inoculum capable of attempting to colonise their new environment for many years. To prevent such threshold of dinoflagellate cyst introduction would require a ballast water treatment efficacy of 99,99997%. This exercise raises serious doubts about the value of e.g. ballast water exchange for this particular target species while favouring technologies such as heat treatment (Rigby & Taylor 2000).

Seaweed spores

Brown seaweed beds comprising genera such as *Laminaria, Macrocystis, Undaria* produce approximately 10^9 zoospores/ m^2/ year (tom Dieck, I. 1993). Assuming fertility for 6 months of the year (180 days), potentially a ship can take on $5 .10^6$ zoospores as ballast water or alternatively as hull-fouling. Unlike dinoflagellate cysts, seaweed spores are subjected to significant mortality, but even with a 0.04% survival we still can expect the development of 2,000 mature reproductive plants (sporophytes). Again, even a 95% effective ballast water treatment (leaving 100 sporophytes) would be sufficient to start an invasion.

Starfish larvae

Spawning events by the introduced starfish *Asterias amurensis* can produce larval densities up to 1000/ m^3 in the Port of Hobart (Bruce et al, 1995). If this were to be taken up by a vessel with 20,000 tonnes ballast water capacity, the mortality rates would be significant but even with a 0.1% survival one would have 20,000 larvae left. The major difference between starfish larvae and resistant dinocysts/seaweed spores, is that ballast water exchange and or treatment technologies such as filtration would also significantly enhance starfish mortalities. Furthermore, the precarious nature of larvae settling and eventually growing up into reproductively actively adults would incur further significant mortalities along the track, even after a successful ballast water introduction.

Conclusions

Considerations on what constitutes minimum viable populations for marine pest species provide a sobering reality check on the desired efficacy of ballast water treatment technologies. While it is tempting initially not to set the "bar height" too high, laboratory treatment conditions will always be more favourable than real ballast water tank situations (with complex tank wall effects, hidden corners, sediment interference). Accordingly, the level of inactivation achievable under controlled treatment conditions should be close to 100%, in the same way that costly efforts to eradicate established pest populations cannot afford to leave even a few viable individuals.

Acknowledgements

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Possible BWT Standards: The Aquatic Science Perspective

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Introduction

You may expect an aquatic scientist to seek the unattainable ideal of zero discharge of all aquatic organisms in ballast water. But as you will see, aquatic scientists have many reasons to be pragmatic. It would be correct, however, to assume that not all aquatic scientists agree with any given approach, and that there is no (and could be no) official unanimous aquatic science perspective. However, there are commonly held aquatic science concerns related to ballast management standards. I will describe these and an approach to standards which emerges from them for your consideration. I have presented the approach to the International Convention for the Exploration of the Sea Working Group on Ballast Water for comment and will summarize their input as well. This policy approach combined with a technical approach to defining "acceptability limits" for various biotic groups (such as that presented by Norway) could comprise a powerful tool for assuring practical standards that are also scientifically sound.

In general, aquatic scientists will seek standards which 1) yield meaningful reductions in risk to the environment; 2) are expressed in specific, measurable terms that allow comparison across treatment/management methods; and 3) are flexible over time to accommodate improvements in science and technology surrounding ballast mediated invasions. In light of present uncertainties, and the rapid rate at which science and technology are developing, the proposal here is to apply the "Best Available Technology Economically Achievable" in an iterative process (i.e., one that develops over time) with evolving goals for ships:

- As an initial goal, if necessary: Reduce the probability of ballast mediated species transfers of zooplankton and benthic organisms (biotic groups known to present a risk and expected to be most readily and productively controlled with the present suite of tools) combined with optional absolute discharge limits on selected additional biotic groups or target organisms (e.g. phytoplankton, fecal coliform, and/or toxic dinoflagellates) consistent with controls on other types of sources.
- As a practical near-term goal: Remove ships from "leading source" status in unintentional transfers of aquatic organisms in all taxonomic groups;
- As an ultimate goal, once definable, and applicable to all sources: Protect receiving systems and public health from harm by transfers of harmful aquatic organisms and pathogens.

Aquatic science requirements for ballast management standards

Meaningful reductions in risk

From the aquatic science perspective, a ballast treatment standard must first and foremost yield results for the environment, i.e. measurable reductions in risk of ship-mediated species transfers and invasions. This fact dictates several specific requirements:

The standard must be implemented

Some versions of ballast management standards will have no real relevance to aquatic systems because they will not be implemented. For example, a voluntary set of standards with insufficient incentive for industry is tantamount to no standards from the aquatic science perspective.

Similarly, overly ambitious, unachievable or environmentally unsound standards that are postponed--or worse, stopped in the courts--are equally useless to aquatic science. We know that unfettered species transfers cost society a great deal of money every year, probably dwarfing the expense of sophisticated treatment systems on ships. One very limited economic study found that the zebra mussel (just one of numerous invaders) created direct market impacts on industrial raw water users (just one of many costs) in the Great Lakes system (just one of the regions infested) of over $20 million a year for the five year study period (just a short period of time). We can only imagine the costs associated with all of the impacts of the zebra mussel, and its counterparts and their impacts (including human health) in all of the systems around the world. Still, a treatment standard which imposes indefensible or unnecessary economic costs on ships will generate resistance and slow progress toward environmental protection. This is a reality.

In the same way, treatments which seek to reduce costs on ships through creating unacceptable environmental impacts will also generate resistance and slow progress. For society, such "solutions" are in fact quite costly because they create new problems that must be fixed. Fortunately, industry and environmental interests coincide on this point as reversals are costly for industry as well.

Thus, the best standard is one that is effective while minimizing both economic and environmental trade-offs. Hence the aquatic scientists' pragmatism: for standards to reduce risk, they must be implemented.

The standard must be sensitive and responsive to biological "reality"

<u>Differential organism (especially reproductive) properties of taxonomic groups</u>

Here I refer to major groupings like benthic organisms and zooplankton (planktonic animals), phytoplankton (planktonic plants), and microbes (bacteria and viruses). A single limit applicable to all of these groups, while apparently most simple, will unfortunately likely require some control actions that are not meaningful from an aquatic science perspective because the organisms themselves are quite different. A meaningful reduction in zooplankton is different to a meaningful reduction in microbes. For example, a 95 percent reduction in zooplankton concentrations relative to intake is likely to reduce risk to a receiving system because these organisms have sexual reproduction and must occur in high enough concentrations to "find each other" in their new home. On the other hand, as our research showed on the *M/V Regal Princess* and the barge platform, a 95 percent reduction in bacteria and some phytoplankton, which occur in extremely high numbers (millions per milliliter), and regrow readily regardless of initial concentrations, can be negligible from the standpoint of the receiving system. Worse, partial reductions in organisms which rapidly regrow asexually can lead to selection for resistant individuals. It is equally possible, though not yet demonstrated, that partial reductions in bacteria could have the positive effect of eliminating more specialized pathogenic organisms. The answer is not a straightforward one, yet efforts to control bacteria may entail much more and/or a different type of effort than plankton. Standards should require reductions in these rapidly regrowing and numerous organisms only if the reductions are both attainable *and* likely to be meaningful from the standpoint of the receiving system. Clearly, transfers of microbes and phytoplankton probably do pose a risk to receiving systems, and work must continue toward findings solutions which do in fact yield meaningful reductions in all biotic groups.

<u>Macro-scale species spread</u>

Similarly, a standard which yields only isolated loci of treatment intensity (as opposed to geographically widespread attenuation of species transfers) is in the long run, from an aquatic science perspective, also of little utility. This principle applies to organisms within any biotic group. Each new population of established invasive organisms becomes a hub from which many "spokes" of organism spread will emanate. The spread will be by a myriad of anthropogenic and natural means. Whether or not localized ballast treatment occurs, say into the Great Lakes or San Francisco Harbor, invasive organisms with many hubs will find their way to that system, if not by one means then by another. Thus, to yield meaningful reductions, the standard must reduce the number of new hubs created globally, as well as the number of non-native species which may enter a given system.

Standards which embody "ecosystem-matching" principles to achieve this global attenuation of spread, but which are based on assumptions which have not been empirically tested for validity, may not be relevant from the aquatic science perspective. Clearly, a decision support system which *should* significantly reduce transfers of invasive organisms, but in reality, fails to do so because one or more underlying assumptions are not accurate, is of little practical utility. Any such system, even once tested, should be accompanied with an on-going rigorous means of reviewing and revising baseline assumptions.

The standard must require environmentally sound methods

Here, the distinction between environmentally acceptable and environmentally sound is important. Technologies which gain acceptability (like TBT once did) but are not in fact environmental sound are of great concern from the aquatic science perspective. In addition to the political concerns cited above, techniques which may be "accepted" but harmful replace one pressure on the environment with another, they are of marginal utility to the protection of aquatic systems. In the absence of a "green bullet' in the near-term, environmental trade-offs associated with meeting a standard of effectiveness must be held to a minimum and necessarily reduced over time. Sources of environmental trade-offs include chemical treatment residuals and by-products, thermal pollution, mutations, production/use waste, and operational impacts (such as air emissions associated with ballast water exchange).

Measurable and cross-comparable

Another criterion of great importance to aquatic science is that the standard be specific enough so that all parties seeking to evaluate methods against it know what to measure, can carry out the measurements effectively, and measure in the same way. The standard must:

- Describe a Common Treatment Endpoint - If we say a 95% reduction in some set of organisms (zooplankton, phytoplankton or microbes), do we mean removal, mortality, reproductive inactivation, or some combination of the three options? Do we refer to the natural assemblage upon intake or some standardized set and concentration of sentinel species?

- Require Routine Measurements - A second consideration is that performance against the standard be measurable using methods to which scientists have ready access to around the world. Perhaps fortunately, this requirement tends to limit our options for the measurement end-point choice noted above. It is fairly difficult to culture zooplankton, so detecting reproductive effects can be difficult. Measurement in terms of reduction in live density (which considers both removal and mortality), while an underestimate, is more practicable. For bacteria and phytoplankton, on the other hand, a "grow-out period" is a routine means of detecting changes in live numbers, so consideration of reproductive inactivation is not only feasible, but almost necessary.

- Define Performance at a Common Ballast Management Stage - Another variable is the point in the ballast operation that the measurement is made. As our research showed, bacteria tend to increase in a ballast tank, while exposure to the pump and retention in a ballast tank can diminish live zooplankton density over time. If we say, for example, we seek a 95 percent reduction in zooplankton, we must first indicate whether that measurement is to be made relative to intake concentrations or relative to concentrations upon discharge had no treatment occurred (relative to control). We must also indicate whether the post-treatment measurement is made immediately following treatment, in the ballast tank following a specified period of time, or upon discharge.

- Identify Critical Environmental Parameters - Another challenge is qualifying (or standardizing) the measurement with the environmental conditions that may influence the outcome but which may vary across aquatic systems, such as physical/chemical source water conditions.

- Factor in Application Frequency Across Voyages - The standard must also take into account the frequency with which the method will be used across voyages if that is in any way limited (e.g. BWE is limited to transoceanic voyages).

- Apply to all Methods - The measurement must apply equally well to treatments across-the-board, including ballast water exchange, so that valid comparisons can be drawn. In particular, known near-coastal sentinel organisms should be identified and specified for comparing live density reduction capabilities of treatment with BWE.

Accommodates both urgency and a rapidly evolving state-of-knowledge

Current knowledge/technology is insufficient to set "be all/end all" standard

At present, there is no ballast management method that can "do it all." A treatment may emerge tomorrow which dramatically reduces all biota in ballast systems, and is both environmentally sound and economically feasible. I hope so. However, it is also possible that such a treatment may be years away, or never to be found, and that our options will have less than perfect effectiveness, if they are to be economically and environmentally sound. We do not yet know where on the spectrum between perfect and imperfect effectiveness today's and tomorrow's technologies will fall.

In light of this reality, aquatic scientists are faced with making recommendations for ballast treatment standards in the context of many unanswered questions. At present we do not know many things that are crucial to defining a standard given imperfect technical tools. How much reduction is enough to reduce risk associated with each of the taxonomic groups of concern? Can we reduce risk through focusing on a subset of voyages through ecosystem-matching? Are some taxonomic groups more likely to be invasive than others? Most of our experience is with invasions caused by zooplankton transfers, but this fact could reflect only our greater ability to detect and identify zooplankton especially in macroscopic adult stages, rather than lower risk associated with phytoplankton and microbes. We know that ships can carry viable human pathogens in their ballast tanks, but we do not know if the ship source of pathogen discharges is significant relative to other pathogen vectors. Most important, we do not know why organisms which are not invasive in one environment become invasive in another, making our known list of target organisms only a small subset of potential invaders. We do know that there are many variables that may influence the probability of an invasion, and that these variables are not constant from one day to the next in a given source and receiving system.

Yet, the need to reduce the rate of organism transfers by ships is urgent

Scientists cannot afford to "wallow" in the morass of unknowns, however. As we speak irreversible damage yet to be documented is occurring as a result of ballast transfers of organisms. The Ballast Working Group of the International Convention for the Exploration of the Sea spent three days attempting to scope the progress of infestations that are occurring in Europe alone. Moreover, new ships are coming on-line every year which could be built smarter to minimize the odds of species transfers by ballast water. The longer we delay in getting started, the more ships will be built no better equipped for ballast management than those in use today.

Fortunately, knowledge/technology can and will improve, if we let it

Acting in the context of uncertainty will eliminate it. If we mobilize research and development toward a target, we can determine if that target is attainable. If we never set a target, because we cannot be sure of its accuracy, we will never know what can be done. If we keep at it, within five years, we could have working estimates for the effectiveness of BWE relative to other approaches to ballast treatment for each class of ship. We can shed substantial light on whether reducing concentrations of all microbes in ballast discharges is beneficial to receiving systems, or whether composition of the microbial community should be our target. We could assess the relative risk to humans and wildlife of pathogens carried in ballast water versus those entering aquatic systems by other means. Within ten years, if we keep at it, we can estimate the residual risk posed by the five percent of live zooplankton that would be discharged, post-treatment, into receiving systems with a 95% reduction standard. We can ground-truth and improve the precision of assumptions behind ecosystem matching approaches to risk reduction.

Meanwhile, we can expect constant improvements in the treatment and measurement tools available, including improvements in treatment technology effectiveness and efficiency (including environmental soundness). But only if we get started, and keep at it. A preliminary performance goal (set in the context of unknowns) is essential to organizing this data-gathering and information-development effort, in the same way that an experiment benefits from a hypothesis.

Straw proposal - ground rules

In light of the points above (aquatic science concerns, present unknowns, urgency, and expected improvements in knowledge), I put forward the following proposed approach and accompanying questions for discussion during the workshop.

Start with best available technology

We do not yet have the science to define biology-based standards (absolute concentrations of organisms that do not pose a risk to receiving systems), and we do not have the technology (without significant trade-offs) to deliver "zero discharge". In the absence of these things, this proposal suggests the use of "Best Available Technology Economically Achievable" (BAT) as one fundamental basis for standards. Best available technology is not a stand-alone consideration. It will vary depending upon the prevention goal, the number of taxonomic groups covered, stringency and the precision of the standard relative to ship classes and voyage types, and technological developments.

Guarantee review and revision at least every five years

BAT changes over time with our understanding of the hazards to be prevented, and with developments in the technologies available. Review and revision must be periodic and dependable. Early reviews should be triggered by a) newly discovered public health or environmental hazards; and b) leaps in available technology capabilities, i.e. if the "silver bullet" or "green bullet" or both suddenly become available, the standard should be revised immediately to reflect it.

Assign most advanced prevention goal possible (given bat) to each age/class

In the introduction I outlined a set of evolving prevention goals. These are:

- As an initial goal, if necessary: Reduce the probability of ballast mediated species transfers of zooplankton (a taxonomic group known to present a risk and to be most readily controllable). Absolute discharge limits on selected target organisms (e.g. fecal coliform, and/or toxic dinoflagellates) may be added as well, consistent with controls on other types of sources.
- As a practical near-term goal: Remove ships from "leading source" status in unintentional transfers of aquatic organisms in all taxonomic groups.
- As an ultimate goal, once definable, applicable to all sources: Protect receiving systems and public health from harm by transfers of harmful aquatic organisms and pathogens.

This set of evolving goals represents pragmatism from an aquatic science perspective, because clearly the gravity of the problem of harmful aquatic organisms and pathogens warrants a zero discharge goal immediately, if that were possible. You will note that the stated goal of the current IMO voluntary guidelines is most consistent with the final goal stated here.

For a given age/class of ships, we start with the most advanced goal feasible given available technology. Clearly, more options are currently available for new ships than existing ships, therefore the second or third goal could be applied to new ships from the outset, while the first or second goal may be most applicable to many existing ships. Similarly, more options may also be available for ships with lower ballast water flow rates, such as container ships and passenger ships, than ships with rapid or large ballast capacities. Voyage pattern may also be an important variable.

Focus on meaningful reductions given properties of organisms and ships

As noted earlier, different organisms require different levels of reduction before a reduction in risk registers with a receiving system. Here the "acceptability limits" suggested by Norway should be defined relative to each of the goals across taxonomic groups. For example, the first goal could be satisfied by any technology that achieves a 95% reduction in live zooplankton and benthic organisms relative to intake in ballast discharge water and perhaps also meets an absolute discharge limit relative to a target organism.

The second and third goals would add biologically equivalent (though not necessarily numerically equivalent) reductions in phytoplankton and bacteria in keeping with acceptability limits reflecting the nature of each taxon and the desired endpoint for the environment. The limit on zooplankton also may be lower than for the first prevention goal.

Set up rigorous safety and environmental soundness screens

Ship classification societies will certify technologies for their safety, and ship-owners will scrutinize the risks of "grey areas" once standards are set and options for meeting them are offered. In the same way, the standard should incorporate a process for environmental soundness certification and risk identification so that nations can likewise scrutinize "grey areas" and respond to them as needed.

Guarantee approval for a minimum of five years

Approval should be valid for five years regardless of when in the standard revision cycle approval is obtained. The only exception to this rule relates to the first goal in which zooplankton may be the sole subject of the control system. Systems approved under this goal should be required to provide a strategy for how they would upgrade the system to be protective against phytoplankton and microbes in case a health hazard should arise. If a health hazard is identified then those ships must upgrade the treatment system sooner than five years, according to the strategy.

Define common metric, generic to range of treatments

A standardized process for measuring treatment performance against the standard should be developed and included in the standard requirement. This standard should specify a limited set of operationally simple and effective approaches to certification of treatment processes, and mechanical monitoring for approved systems. The system of certification and monitoring will not be perfect, but above all should provide a practicable and standardized estimate of system effectiveness. Treatment effectiveness is influenced by properties of ships, organisms and source water. Therefore, precision also is required in defining surrounding physical, chemical and other conditions which may influence treatment effectiveness findings in the standard setting process. Relevant variables include:

- Ship Properties - Treatment Point in Ballast System
- Treatment Properties - Voyage Pattern, Physical/Chemical Limitations
- Organism Properties - Regrowth Potential
- Source Water Properties - Transmittance, Turbidity, Temperature

Straw proposal - example terms

To spur discussion, I will go out on a limb and propose an actual set of standards for existing and new ships of large flow-rates. It must be understood that these standards are being proposed in the interest of creating a starting point, and that revelations regarding the capabilities of technology, or new information on the hazard that specific organisms pose to receiving systems should (according to the ground rules outlined above) lead to revisions that might make standards such as these more stringent or even more lenient.

Existing ships

The standard for existing ships would be based on Goal 1 and would consist of three linked provisions. Below each provision I list a set of rationales.

Proposed Provision 1: >95 percent reduction in live zooplankton and benthic organism concentrations relative to intake.

- Consistent with Goal 1, this approach targets a set of taxonomic groupings known to be successfully introduced to new regions via ballast water.
- Risk reduction is likely through a 95% reduction in concentrations transferred given the reproductive requirements of these organisms.
- Near-term technologies are likely to be able to achieve effective levels of control of these organisms in ballast systems.

Proposed Provision 2: Optional absolute discharge limit(s) for known hazards (addresses target species, such as toxic dinoflagellates or fecal coliform).

- Individual regions and jurisdictions may have an urgent need to control discharges of target organisms, or even existing limits on other sources that they wish to apply to ships.
- Not all jurisdictions have these constraints/needs.
- Certain ship-owners may wish to exceed the initial standard on a voluntary basis, and these additional limits provide a benchmark.

Proposed Provision 3: All ships must include in ballast management plan, a strategy for additional controls (of microbes/phytoplankton generally) to be deployed if a public health threat is identified.

- The focus on zooplankton and benthic organisms in the initial standard is reasonable given best available technology constraints, but presents some risks because it requires nothing to control potentially pathogenic organism categories.
- Information could emerge that would make control of microbes and pathogens necessary despite high costs.
- A strategy would create “preparedness” at relatively low cost to industry, and allow deployment only as needed.

New ships

The initial standard for new ships would be based on Goal 2 and would consist of the following provisions:

Proposed Provision 1: >95 percent reduction in zooplankton and benthic organisms, phytoplankton and microbial concentrations relative to intake.

- Risk of additional taxonomic groupings could be mitigated by a 95 percent reduction, especially if one considers compositional dynamics.
- Larger reductions could restrict technical options to chemicals only at this stage of research and development.

Proposed Provision 2: Larger reduction pursuant to regional requirements and as desired on a voluntary basis (Same rationales as above).

Proposed Provisions 3: Strategy for 99.9999 percent reductions (six logs) of phytoplankton and bacteria (Same rationales as above).

Need for interim approval status

During the period prior to any IMO agreement on a first ballast treatment standard, an interim approval process should be established and honored. The availability of an interim approval status is crucial to continued innovation, and research and development of treatment capabilities. The same ground rules as those proposed for the initial standard for new and existing ships should apply (five year approval period, plan for upgrade if necessary, etc.). Interim approval of any given treatment system should be limited to a small number of ships (fewer than five). Interim approval should be predicated on substantial (though not necessarily definitive) evidence that the proposed system is likely to exceed BWE effectiveness for the host ship. Petitioners should also have to show how the system's effectiveness would be likely to exceed that of other technologies granted interim approval. Finally, ships granted interim approval status for proposed treatment systems should allow research on system effectiveness during the approval period.

Comments from ICES biologists

The discussion with ICES biologists yielded important informal feedback on this set of proposed ballast treatment standards. In general, there was agreement that starting somewhere, and starting soon, is crucial. It was also accepted that starting with zooplankton and benthic organisms makes sense given expected present-day treatment system capabilities and the reproductive properties of these organisms (improving the odds that a 95 percent reduction in numbers of organisms transfered might reduce risk to receiving systems). There was some concern that phytoplankton are indeed a known risk for ballast-mediated transfers, and that a standard that focuses on zooplankton might discourage the development of technologies capable of tackling phytoplankton. This concern was balanced by concern that too aggressive a standard for technologies at this stage could lead to continued use of the ballast water exchange option. The zooplankton-oriented starting point for existing ships is reasonable therefore, only if it is in fact accompanied by a broader standard for new ships, optional additional standards for target organisms, and the requirement that all ships show how they could upgrade their systems (if necessary for public health reasons) to tackle phytoplankton and microbes. These additional components will help assure continued progress toward treatment systems that provide comprehensive protection for the environment.

Conclusion

In summary, to be of value from the aquatic science perspective, ballast treatment standards must be fashioned in such a way that they 1) are implemented, soon; 2) achieve meaningful reductions in risk to the environment and public health (including through minimizing and progressively reducing any ancillary impacts of the treatments themselves); 3) are measurable and cross-comparable in a standardized manner, and 4) are subject to dependable periodic review and revision. Most important, the standards must be constructed to motivate continued innovation, research and development of improved treatment systems. Standards should address progressively more ambitious prevention goals for the ship-vector within the constraints of best available technology, and start at the most advanced prevention goal possible for various ages/classes of ships. While an initial focus on zooplankton and benthic organisms is reasonable for existing ships, a broader focus on phytoplankton and bacteria should be pursued for some existing ships and all new ships.

Possible Ballast Water Treatment Standards: An Engineering Perspective

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Introduction

The topic of rendering ships' ballast water innocuous with respect to the transfer of unwanted species has been debated for well over ten years. The International Maritime Organization (IMO) has had ballast water issues on its agenda for the past 13 years. However, to date, limited progress has been made with regard to the development of processes and procedures for halting the transport of unwanted species via ships' ballast.

Currently, the IMO and various port states, are suggesting that exchange of inshore ballast water with "high seas water" is at least a temporary procedure to diminish the risk of transport of unwanted species. Because of the inherent safety issues associated with ballast water exchange, however, and concerns regarding the effectiveness of the procedure on existing ships, movement has been slow to adopt "ballast exchange" worldwide. In lieu of ballast exchange, it should be possible for ships to treat ballast water to a level, such that most organisms are unable to survive any voyage in the ballast. While several efforts are currently underway to evaluate treatment techniques, the fundamental issue: i.e. there are no treatment standards, or goals for treatment, has essentially halted any positive movement of these endeavors. In fact, at this point, there is essentially no consensus concerning the level of required treatment, nor any ongoing work attempting to investigate organisms which need to be precluded from ballast water. Because of this worldwide inability to deal with treatment criteria, ballast water treatment (other than exchange) has not made any measurable progress over the past few years.

Part of the reason that a solution for the issue of ballast water transport of unwanted species has not been achieved, is its inherent complexity. *However, a solution must be found*, therefore, this complexity *must* be bounded in a way that reasonable and productive solutions can be generated. In order to start this process, it is necessary to retreat to the beginning of the ballast issue and slowly retrace the path which many have walked over the past ten years. The reason for this exercise is to establish a base of consensus on several issues which constitute the core of this problem. Once a basic consensus is reached on these issues, then the path forward, that is, development of treatment technologies and standards, will become more clear.

Defining the ballast water issue: *reaching a consensus*

The first point to address is the seemingly naïve question, *is there a documentable problem?* Strangely, this type of simple question has often been a "stumbling block" in dealing with environmental issues. However, in this case there is a substantial literature base documenting the global inoculation and colonization of invasive species, both aquatic and terrestrial. In fact, there is not only extensive documentation of the invasive occurrences, but more importantly, there is a growing body of literature associating societal costs of these invasions. Some of the cost estimates are astronomical, which points to this as a major global problem. In addition, there appears to be little debate suggesting that the translocation of potentially invasive species is not a problem. It appears then, that all stakeholders, e.g. the maritime industry, government, and concerned citizens, agree that the transportation of unwanted species via ships' ballast water, poses a substantial threat to aquatic environments around the world.

Summary

- The consensus on this topic should be that the transportation of unwanted species around the world via ships' ballasting procedures poses a significant global threat to ecosystems.
- There also appears to be a consensus amongst all stakeholders, that the societal cost of invasions is large, and therefore, immediate and appropriate attention to this problem should be undertaken.

This is <u>not</u> a public health issue: *reaching a consensus*

In order to focus on appropriate remediation policies and procedures, a definition and understanding of the ballast water issue must be reached. Specifically, whether or not this is a typical public health issue. If it is, then policies and procedures for its solution will follow well documented pathways established to deal with the prevention of communicable diseases.

The hypothesis presented here is that the translocation of unwanted species via ships' ballast water is <u>not directly</u> a public health issue. While there are associated environmental health concerns, they are secondary, and should not greatly influence the procedural policy for solving the ballast water issue. In fact, it should be agreed that the translocation of unwanted species via ships' ballast is an <u>invasive species issue</u>, and significantly different in structure from environmental or health related problems. Therefore, the solution to this problem is expected to be different, and probably more complex.

The basis for this hypothesis is that public health issues generally deal with communicable diseases caused by human pathogens, which are basically small in size (microorganisms). Because of this small size, (less than 1 micron) these organisms tend to be already distributed around the globe. It is well known that diseases of a public health concern, such as cholera, have occurred in regions all over the world. The possibility of an outbreak of a disease such as cholera, however, is not based on an *invasion* of the causative agent (*Vibrio cholerae*), but due to the failure of the public health infrastructure of a society. The basic sanitation infrastructure in developed societies has evolved to protect the human population from all communicable diseases, specifically by breaking the transmission vector of a causative agent in at least two different areas: 1) potable water protection, and 2) wastewater disinfection. When these mechanisms fail, then the possibility of an outbreak of a communicable disease becomes a reality, regardless of the "origin" of the causative agent.

Summary

- The consensus on this topic should be that the possible translocation of microorganisms responsible for diseases of public health concern, should play only a secondary role in the ballast water issue.
- <u>The ballast water issue is an invasive species problem</u>, and must focus on the prevention of invasions by organisms substantially larger and more biologically complex than bacteria or viruses.
- Microorganisms of public health concern are already distributed around the globe, and continue to be transported in large concentrations on a daily basis via transiting humans.

Global versus regional ballast water standards: *reaching a consensus*

As noted earlier, the only treatment process currently practiced for control of transport of unwanted species via ships' ballast, is ballast exchange. As was also noted, this is considered only a temporary solution and its practice is not mandated except in isolated situations around the world.

Discussions within the Marine Environmental Protection Committee (MEPC) of the IMO concerning the issue of ballast water and treatment to prevent transport of unwanted species, have emphasized the need for global regulations. This is desired so that the maritime industry does not have to face different regulations and standards at different ports of call. This wish appears to be common to all stakeholders; however, because of the labored movement towards a solution by the IMO, concerned port states have initiated their own regulations. Countries such as Australia, USA, Israel, Chile and Argentina, for example, have mandated some level of ballast water treatment for ships entering their port states. Therefore, the hoped-for unified standards concept, appears unlikely, as additional port states are considering ballast water treatment requirements.

The hypothesis presented here is that there must be both global and regional standards established for prevention of transport of unwanted species via ships ballast water. It appears clear that the generation of global criteria for treating ballast water to a level which significantly reduces the risk of invasion by all unwanted species, is unlikely. It must be accepted that the concept of biological invasions and the parameters surrounding these invasions are far too complex to allow for a meaningful global prevention scenario. Specifically, the types of organisms that may be invasive in different parts of the world are significantly different across not only species, but genera and family. Therefore, to impose regulations that would prevent the transfer of all organisms via ships' ballast water, would inflict undue hardship on the maritime industry. In addition, there are clearly situations where invasions could not occur due to ballast water discharges; e.g. scenarios where there are already similar organisms residing, and in situations where temperature and salinity differences are so severe, that organisms cannot translocate. Also, there may be situations where the volume of ballast water exchanged, is so small that a viable inoculation would not be possible. In addition to the straightforward scientific explanations of why the risk of invasions would be minimal, there are political and governmental issues to be considered dealing with the transport of goods via ships between port states.

It should also be obvious that treatment procedures for effectively controlling transport of unwanted species via ships' ballast water will be expensive. Considering the magnitude of goods transported via ships, this extra cost will become a burden to our global society. It is therefore incumbent on organizations involved in these decisions to find solutions which are cost effective, while generating the highest level of protection possible against the translocation of these unwanted organisms. To this end it makes little sense to mandate that a ship must treat ballast water to remove organisms such as marine microalgae, when these ships are exchanging ballast in the Great Lakes. Also, it is not cost effective to mandate that ships travelling from cold arctic or sub arctic waters treat ballast, when their ports of call are in the tropics.

Therefore, we will require different types of standards dealing with the quality of ballast water allowed to be discharged. That is, there should be one global set of standards that will focus on those organisms most likely to become invasive, and an identification and validation of technologies and procedures to reduce the risk of their translocation. There will also be different standards which will address specific classes of organisms of concern to specific port states. These *extra* standards (treatment requirements) must be addressed by ships doing business in specific regions. These standards, issued by individual port states, can be more specific than the global regulations, but they should not be allowed to be less rigorous.

Summary

- There should be a consensus that at least two levels of ballast water quality standards will be developed. One set of quality standards will be issued on a global basis (via IMO), and will focus on reducing the risk of translocation of species which are documented to have been transported and caused invasions.
- Standards will also be developed by individual port states and will address regional concerns of natural resources. These standards will be region specific, and will effect ships doing business within that region.

Treatment levels equivalent to ballast exchange: *a consensus*

The starting point for development of technologies for treating ballast water to prevent the transport of unwanted species must be based on existing laws, at least in the United States. In that respect, the National Invasive Species Act (NISA) of 1996 stipulates that any treatment of ballast water must be at least as effective as ballast exchange.

The mandate of ballast exchange as a procedure for preventing the transport of unwanted species, seems a simple and straightforward concept. The generators of NISA were under the impression that if inshore water, which possibly contained invasive organisms, was exchanged for “high seas water” during a ship’s voyage, then a simple solution to a complex problem could be easily generated. The fundamental concept is that open ocean water would not contain organisms which could pose a significant invasive threat in inshore waters of any port state. In addition, it is obvious from the dialogue in 33CFR Part 151, Notice of Proposed Rulemaking (Fed. Reg./Vol. 63, No. 69/Friday April 10, 1998) that the USCG believed this solution could be readily implemented on existing ships, at a minimum cost.

It has become apparent that the ballast exchange process in itself is not simple, and has a high variability with respect to efficiency, depending on the configuration of ships’ ballast tanks. It should also be apparent that existing ballast tanks were not designed, and are not operated to optimize the ballast exchange process. In addition, material heavier than the water, such as sediments, tends to settle in tanks and therefore can not be easily removed through typical de-ballasting procedures. Safety concerns surrounding the ballast exchange process have also been articulated by the shipping industry, and many ships are currently reluctant to exchange ballast while underway. The simplistic notion that a ballast tank could be emptied of inshore water and refilled with open ocean water, has proven misleading, as the induced stresses in the ship during this process, often exceed allowable limits. The most acceptable method for exchanging ballast then, is a continuous flow-through system where water is continually diluted by open ocean water, while a ship is underway. While this process of exchange alleviates the induced stress problems encountered with the empty and refill procedure, the efficiency of exchange now becomes dependent on the volume of dilution water actually pumped through the tank, and tank geometry.

Studies of ballast exchange issues on existing ships have demonstrated clear operational and safety constraints to the process. In addition, because ballast exchange efficiency by dilution is much different than emptying and refilling a tank, separate legal definitions for ballast exchange are required. It should be obvious, that by completely emptying a ballast tank and refilling it with open ocean water, an exchange of 100 percent is accomplished, and also such a level of exchange cannot be attained during a continuous dilution process. To address this issue, the USCG (33CFR151), defined the ballast exchange process using the dilution method to have taken place when an equivalent of three tank volumes of water have been pumped through the tank. According to Code of Federal Regulations, Title 33, Volume 2, Parts 120 to 199 revised as of July 1, 2000, Site: 33CFR151. Section 151.2025, exchange means to replace the water in a ballast tank using one of the following methods:

a) *“Flow-through exchange means to flush out ballast water by pumping in mid-ocean water at the bottom of the tank and continuously overflowing the tank from the top until three full volumes of water have been exchanged, to minimize the number of original organisms remaining in the tank.”*

b) *“Empty/refill exchange means to pump out the ballast water taken on in ports, estuarine or territorial waters until the tank is empty, then refilling it with mid-ocean water; Masters/Operators should pump out as close as to 100 percent of the ballast water as is safe to do so.”*

In fact, if a ballast tank is well mixed without short circuiting, or dead spaces, a three tank volume exchange would represent approximately a 95 percent dilution. Currently then, there is a fundamental discrepancy in the definition of exchange, as emptying a ballast tank and refilling it, constitutes a 100 percent treatment, while exchanging three tank volumes of dilution water in a flow through system constitutes only a 95 percent treatment level. If there are no changes made to NISA, then technologies that are at least equivalent to exchange, would have to refer to the lesser of the two processes, or a 95 percent treatment level. The ballast exchange process is not organism specific, as it is a straightforward dilution process. Therefore, theoretically everything in the ballast water tank is diluted by 95 percent.

Realistically, some organisms and sediments may behave differently from the water fraction in a ships ballast system, depending on the mixing. Therefore, diluting 95 percent of the water may not necessarily remove 95 percent of the organisms of concern, especially in existing ballast tanks. In addition, as noted above, because existing ballast water tanks are not designed to be completely mixed systems, pumping the "equivalent" of three tank volumes will probably not yield a 95 percent dilution of the ballast water, due to dead zones and short circuiting. However, the hypothesis presented here is that the USCG and NISA intend that a 100 percent of the *risk* of bio invasions will be removed by ballast exchange process. The USCG has modified this number downwards to 95 percent reduction of the *risk*, in a flow-through ballast water exchange process. Therefore, the issues of non-ideal mixing, and variable exchange efficiencies in ballast tanks on board existing ships deal with verification of treatment efficiency only. It should be apparent that if a ship elects to do ballast exchange via a flow through process as a treatment procedure, then each ballast tank will need to be calibrated to determine mixing characteristics, and the actual volume of dilution water required for a 95 percent dilution. It is anticipated that most existing ballast tanks will demonstrate poor behavior with respect to dilution, and therefore would not be a basis for comparing alternative treatment technologies.

Summary

- The intent of the USCG (NISA) in stipulating ballast exchange as a method for preventing the transport of unwanted species is for complete or 100 percent treatment, which can in fact be achieved by emptying a ballast water tank and refilling it with open ocean water.
- The USCG has redefined the exchange process as three equivalent tank volumes exchanged for a flow-through process, which represents approximately 95 percent exchange.
- Most existing ballast tanks on ships are not designed for efficient exchange, however, this issue is separate from the intent of the ballast exchange regulations, and should only be addressed during validation/monitoring exercises.
- All ships should be required to calibrate any ballast tanks utilized during exchange as a ballast management technique. The basis for comparison of alternative technologies is currently defined as a 95 percent treatment level (lowest of the two exchange processes). It should also be noted that the 95 percent exchange value, refers to a dilution of all materials in the ballast water, and no alternative ballast water treatment technology will realistically be able to match this level of treatment.

Policies and procedures for USCG approval of ballast water treatment equipment already exist: *a consensus*

A substantial amount of discussion recently has dealt with the policies and procedures for the approval of ballast treatment standards. For example, in the U.S. the USCG has in place a complete infrastructure for developing such guidelines for approval. The only information lacking in the process of approval of equipment for treatment of ballast water, is the numeric standards to be achieved by the treatment technologies. It should also be apparent that all other concerns associated with establishment of standards and approval of equipment by the USCG are addressed by existing guidelines, and do not require further refinement.

Summary

- All policies and procedures for verification and approval of treatment technologies to achieve a selected standard of ballast water treatment, resulting in approval for shipboard use by the USCG, are currently in place.
- Issues associated with ship safety, environmental harm, and other matters, are also currently addressed by existing guidelines utilized by the USCG.
- The only component missing in the equipment approval process is the actual treatment standard to be achieved by equipment utilized for ballast water treatment.

Table 1. Fundamental Issues Requiring Consensus

A.	The translocation of invasive species is a global problem of enormous magnitude, requiring immediate global attention.
B.	At least two different levels of treatment standards will be required to effectively reduce the risk of translocation of unwanted species via ships' ballast water.
C	The translocation of microorganisms responsible for human diseases by ballast water, while occurring, is of secondary concern due to the existence of public health safeguards.
D	The *intent* of existing ballast treatment efficiencies (NISA & USCG) is 100 percent via empty/refill ballast exchange, and 95 percent via flow through exchange. Ballast water systems on existing vessels are not designed for optimal exchange processes, and will therefore require calibration if used in an on-board ballast water management program.
E	The USCG currently has in-place, policies and procedures for approving ballast water treatment equipment to be used on-board ships. The only element currently missing is the numerical standard reflecting required treatment efficiency.

Possible Standards for Ballast Water Treatment[1] - Netherlands Proposal

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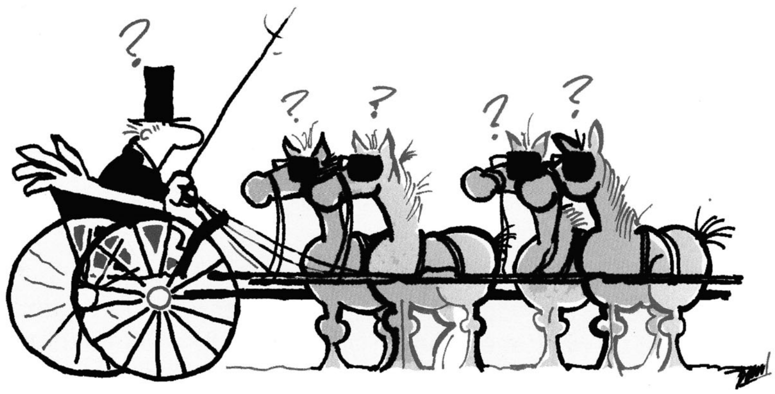
Introduction

After many years of debate in the International Maritime Organisation (IMO) and other fora, the problem of ballast water is more or less recognised. In the current discussion on solving the ballast water problem, a piece is still missing: a link between the problem, and possible solutions. The options available to diminish the problem are subject of debate during the first two days of this conference. If you haven't decided what these technical options should accomplish, it might just be too soon to start talking about which option to implement. Everyone agrees that a standard is needed. But how to proceed? This paper outlines different possibilities, in an attempt to stimulate the discussion.

What guidance should a standard give for ballast water management options? What level of risk should a standard aim to achieve? These are the two most important questions to be answered in deciding on a standard. Once a consensus is reached the IMO has shown, on numerous different subjects, to be highly proficient in formulating standards. An overview of different choices, and their consequences would be a good contribution to help the Marine Environmental Protection Committee (MEPC)[2] towards an agreement on a standard.



The way forward in standards?

Answering the first posed question will show what TYPE of standard should be chosen. In answering the second, the standard is worked out. In contrast, the present discussions focus either on what

[1] This paper is a summary of the report IWACO (2001) *Standards for Ballast Water Treatment*, commissioned by the North Sea Directorate, Ministry of Transport and Public Works, The Hague (51pp, appendices 1 to 3 (31pp)). Obtainable from IWACO Amsterdam (f.tjallingii@rtd.iwaco.nl), or the North Sea Directorate). For references and further detail we refer to this document.

[2] Specifically the Ballast Water Working Group (BWWG) at the MEPC.

performance is sufficient, or what exemptions (grandfather clause, two tier approach) should be included in the legal instrument being formed. The context of these aspects is however still less than clear. This paper provides some ideas on the choices that remain to be made for a standard, and the advantages and disadvantages of the possible answers.

Standards

A standard can be defined as a documented set of requirements or guidelines agreed on by all parties involved.

The development of any standard starts with the basic discussion: Do we want a "You Must Standard" with specific requirements or do we need a "You Should Standard" with guidelines (as in IMO resolution A.868(20)). With respect to a global solution, and need for enforcement, a "You Must Standard" is now gaining momentum. Such a standard should provide exact requirements and clear methods of control, to all parties involved.

In the case of ballast water, the goal of a standard should be to control the risks involved with ballast water discharge to a minimum level that is to be agreed upon. This means that a standard for ballast water treatment[3] should give precise requirements related to reducing[4] the risk of unwanted introductions of alien species. The standard should give a set of criteria by which a technique (or method) for the treatment of ballast water (treatment option) can be judged as to whether it sufficiently reduces the risks connected to ballast water discharge. The standard can play a role in the recognition or indication of an existing or future technique (or method), as suitable for the treatment of ballast water.

Types of standards

In general there are two types of standards. The first is a management standard, which prescribes a procedural and organisational approach, the second is a technical standard, which focuses on technical BW management options.

Management system standard

This type of standard will give overall guidance on how to develop and implement a management system that assumes ships will comply with all relevant legislation. With this approach a universal standard can be established that would allow specific legislation to be different for particular situations[5]. In a management standard the responsibility would be delegated to ship-owners by the port states. In joint agreement measures and procedures are then laid out to treat/ manage ballast water.

Standards of this kind address the following items:

- identification of legal and contractual requirements;
- planning of activities;
- implementation of activities;
- internal control and registration;
- regular review of the whole system.

A management type standard stresses the responsibility of ship owners[6]. The ship owners would be required to agree with local authorities, or their representatives, on the activities they are

[3] Ballast water exchange, as prescribed at present, is seen as a less ideal option than on board treatment techniques. The latter is the focus of this study, and the GloBallast Water Treatment Workshop.
[4] At present there is an implicit agreement that complete elimination is not practically achievable.
[5] Standards that work this way are the ISO 9001 for quality and the ISO 14001 for environmental care.
[6] The ICS and INTERTANKO ballast water management plan (ICS/INTERTANKO 1997) provides guidance for ship owners to comply with the IMO resolution A.868(20). Such initiatives from the sector may result in a management system standard.

required to implement to assure sufficient risk reduction. In this respect regulations will also be required at a national level.

Compliance with this kind of standard can be checked by means of audits on the completeness and effectiveness of the whole ballast water management system, including the procedural aspects of registration and communication. Inspection by (local) authorities will focus mainly on compliance with agreed procedures and less on the particular technical solution implemented.

Technical Standards

Technical standards aim to regulate the BW treatment process. Figure 3 shows three options for prescribing the properties of ballast water treatment options:

- prescribing the process to be used for treatment (process description standard);
- prescribing the performance (output) of the technique relative to the input (performance standard) and;
- prescribing the water quality(output) that has to be achieved by the option (water quality standard)[7].

The last two types of standards require sampling as a means for checking compliance. Standardisation of sampling is also necessary, but is not subject of this paper[8].

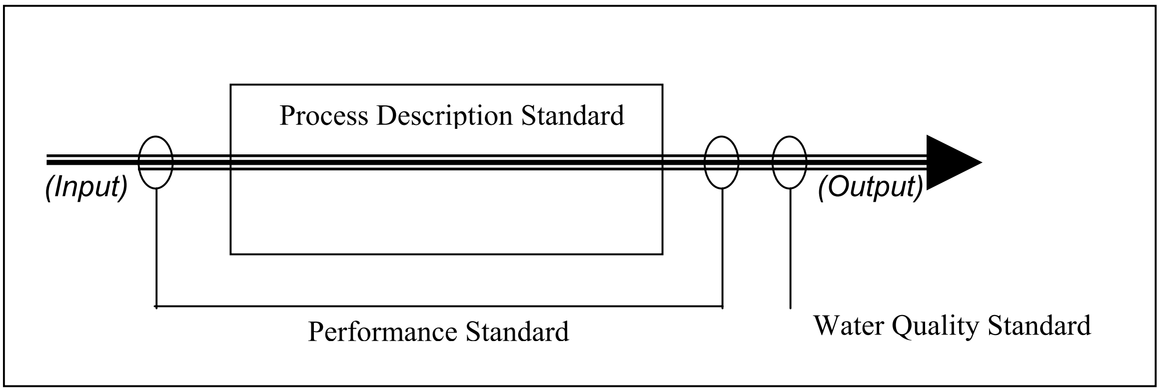


Figure 2. Options for technical standards (The box depicts a ballast water treatment option, the arrow depict the process of treatment (at uptake, discharge, or any other stage)

a) Process standard

This type of standard will prescribe a technical process and how to operate it[9]. In the standard all relevant process conditions are specified in order to control the outcome of the process and ensure acceptable diminishing of the risk of species introduction.

Standards of this kind address the following items:

- description of the process;
- define the requirements for the operation of the equipment;
- define the requirements for the maintenance of the equipment;
- establish internal control and registration procedures, including compliance testing.

It is important to recognise that the actual outcome of the specified process is not a requirement in a process standard.

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[7] Closest resemblance to a "discharge standard".
[8] For work on standardization of sampling see e.g. MEPC 45/2/7.
[9] Although not directly transferrable, the term "Construction, Design, Equipment and Manning (CDEM) standard" bears resemblance.

Compliance with this kind of standard can be checked by means of audits or inspections on documentation such as logbooks, process reports, maintenance reports and certificates of the equipment. Inspection by (local) authorities will focus mainly on the control of documents.

b) Performance standard

This type of standard will give specific requirements for the output of a process relative to its input[10].

Standards of this kind address the following items:

- description of the process;
- define the requirements for the output of the process relative to the input;
- define the requirements for sampling and measuring of the input and output of the process;
- establish internal control and registration procedures, including compliance testing.

Compliance with this type of standard can only effectively be checked by means of sampling the input and output of the treatment installation (or option).

c) Water quality standard

This type of standard will give specific requirements for the output of a certain process. This standard may be referred to as a discharge standard. The difference to a performance standard is that a performance standard prescribes the effort to be exerted for water treatment, and a water quality standard only specifies the result. Therefore in a water quality standard, the necessary effort is likely to differ under changing circumstances.

Standards of this kind address the following items:

- description of the process;
- define the requirements for the output of the process;
- define the requirements for the sampling and measuring of the output of the process;
- establish internal control and registration procedures, including compliance testing.

The standard will prescribe properties that the water should achieve after the process. An example might be the maximum number of a type of organism (e.g. bacteria) in ballast water to permit discharge. This way the actual risk (as far as it is definable by the number of organisms discharged) can be related directly to the requirements in the standard.

In practice a water quality standard can only successfully be audited by means of sampling.

A performance or water quality standard may eventually lead to a process standard. Once the performance or water quality outcome of a process is sufficiently established, the standard may describe the process for ease of checking compliance.

Criteria for standards

The point at which a standard specifies what should be met for compliance can be referred to as a criterion.

A standard can give requirements aimed at minimising risks through different criteria. For ballast water they could be (see figure 3):

(a) maximum frequency of occurrence (maximum risk), (b) species or groups of species to be removed or killed, (c) properties of (groups of) organisms to be removed or killed, or (d) techniques

[10] In MEPC 45/2/8, Germany proposes to set demands to reduction percentages of particles of different sizes in ballast water, and check this with a standardised test kit.

aimed at minimising the presence of organisms. These can be the criteria at which compliance may be checked.

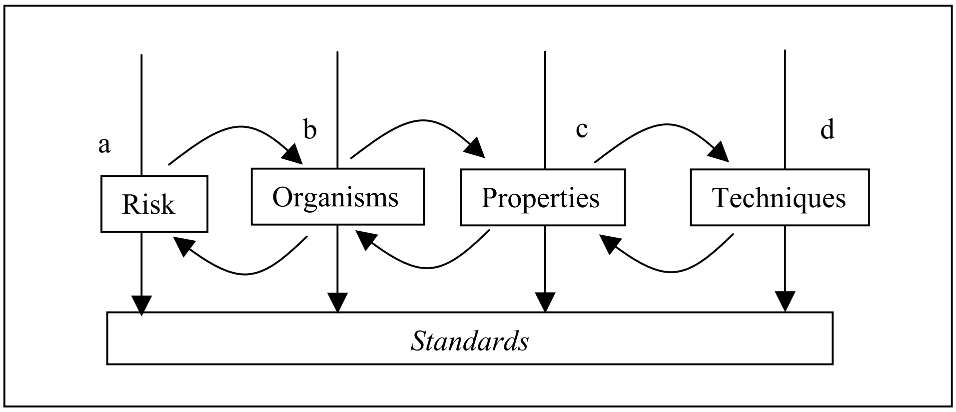

Figure 3. Possible criteria and their links to one another

A process standard by definition specifies a technique or process to be used. The performance and water quality standards can be linked to risks, organisms and properties of organisms, but will not specify what process or technique needs to be used to achieve the standard.

The link between the different criteria, as shown in figure 2 are as follows. The problem of ballast water discharge consists of possible introductions of organisms and pathogens in new environments. The first criterion (risk, (a)) means that a maximum allowed occurrence is prescribed. The risk of occurrence of an introduction is linked to the presence of certain organisms, and the chance that they survive in a new environment. Using the second type of criterion (organisms (b)), means that certain organisms, or groups of organisms are termed "unwanted" (target species) and a prescription is made to prevent these to be introduced. In order to use a technique to prevent the introduction of organisms and pathogens, different techniques may be used. Invariably, techniques use specific properties (differentiating characteristics, susceptibilities) of organisms (Criterion Properties (c)) to remove or kill the organism or pathogen. The last criterion uses techniques (d) as a direct prescription. The technique is linked to risk reduction by the way the technique removes or kills organisms (what property the technique uses, the performance of the technique).

Choosing a criterion

On what basis should a criterion be chosen? The answer depends on two aspects related to the ballast water issue. The first is the risk of introducing new species through the transport of ballast water and what we know about it. The second aspect is a practical one: what can we do about the problem?

Knowledge of the mechanisms behind introductions of alien species and pathogens is very limited. So is (at the moment) the range of feasible technical options to eliminate the problem. How do we choose a criterion that takes these limitations into account, and provides for progress in our knowledge and technology?

When looking at the criteria, there are two extremes in the approach to defining the specifications in a standard (see figure 4, scale on the left hand). On the one end we find prescribing a maximum risk, on the other the prescription of a technique. The first implies, or needs, a thorough knowledge of the mechanism of introductions and the chance of their occurrence. The second implies, or needs, a good knowledge of how techniques function in the mechanism of introduction. The figure below (figure 4), shows choices which can be made, ranging from more theoretical (risk based) to more technical (technique based). In between we find organisms (species/groups of species) and properties of groups of organisms [11].

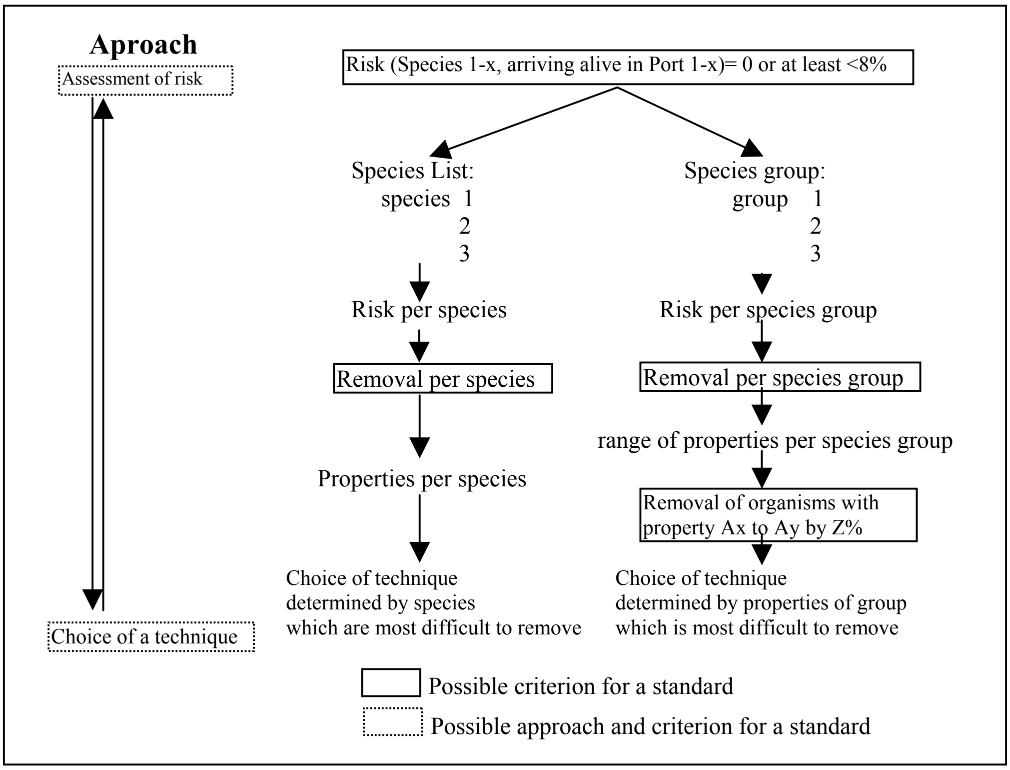

Figure 4. Choices for criteria: between risk, and techniques

Advantages/ disadvantages

The next two tables show possible formulations of the different types of standards (table 1), and of possible criteria for the technical standards (table 2).

Each possibility has specific advantages and disadvantages, these are included in the tables. Named figures serve as illustration, they are explained in footnotes.

[11] Specific properties for species (monoclonal antibodies, DNA techniques) can not currently be used for treatment techniques (they may be suitable for sampling).

Table 1: Types of Standards

Example of formulation:	Advantages:	Disadvantages:
Management Standard		
In close communication with the authorities of the harbours he visits the ship owner will determine the Ballast Water (BW) management actions to be undertaken.	Responsibility with ship owners: Lets ship owners propose the best solution for ballast water management (S[12]). The state of the art of technology can be taken into account (S/A); Flexibility: ship owner and authorities can agree on BW management options as deemed applicable for the situation (S/A).	Checking compliance: Judging activities undertaken under the standard will be difficult (A); Differences between port states: multitude of regulations (S); Competitive differences: some ports will have less stringent wishes towards BW management (S).
Technical Process Standard		
A ship will carry a filtration installation certified by a named institution. Its use is prescribed at BW uptake and must be documented[13].	Easy checking of compliance: is the installation installed? Was its operation documented correctly? (S/A) Ease of definition: An installation is prescribed without need for specification (A); Choice of technique is easy (S/P).	Link to risk reduction: The actual performance is not specified (A); Inflexible: restricts choice of other techniques (S).
Technical Performance Standard		
A ship will carry an installation which removes 99%[14] of all plankton organisms. Its use is prescribed at BW uptake and must be documented.	Equipment can be tested under laboratory conditions (P); Effort prescribed, not result; The effect is relative to the input (S); Room for different techniques and options: it does not specify how the reduction must be achieved (S).	No direct link to risk: The risk remains relative to the BW taken in (A); Checking by sampling is difficult: performance depends on BW taken in (A); Performance will vary: maintenance and wear aspects of the installation influence performance (A).
Technical Water Quality Standard		
A ship will carry an installation which reduces the concentration of organisms to no more than 1 phytoplankton organism per 10 litres[15]. Its use is prescribed at BW uptake and must be documented.	Strong link to risk reduction: effort to comply increases with higher concentration (Risk) (A) Objective check of compliance: by means of sampling (A/P); Equipment can be tested under laboratory conditions (P).	Precautionary approach: limited knowledge of introduction mechanisms may result in low prescribed concentrations(S/P); Need for over-capacity: necessary to guarantee the water quality at all times (S); Compliance at one sampling occasion, does not mean compliance always (A); Difficulty in sampling: The outcome is dependent on the amount of water sampled (A).

[12] Advantage/ Disadvantage for: S = Ship Owner, A = Relevant Authorities, P = Producer of a BW management option.
[13] Documentation includes correct registration.
[14] Choice of figures is arbitrary, ranges spoken of at the moment vary from 90-95% efficiency as in BW exchange to 99% and more using certain alternative treatment options (current pilots).
[15] Choice of figures is arbitrary. A practical figure depends on the amount water that can be sampled and screened for organisms.

Table 2: Criteria for Technical Standards

Examples of formulations:		**Advantages:**	**Disadvantages:**
Risk			
Performance: The risk of introducing species should be reduced a 100 fold[16] a BW management technique.	Water Quality: The risk of introducing species during one voyage may not be more than one per 100 voyages[17].	Maximum flexibility in deciding on techniques (S/P); Strong link to the actual problem of introduction (A).	Limited scientific basis: risk mechanisms are poorly understood (A); Checking compliance is difficult, if risk is not translated to a measurable entity; Leaves decision of techniques to ship owners and checking authorities (S/A)
Organisms			
Performance: The concentration of phytoplankton discharged BW must be reduced by 99%[18].	Water Quality: The number of phytoplankton in the discharged BW may not exceed 1 phytoplankon organism per litre[19].	Link to risk: A group of organisms can be linked to perceived risks and used to decide on techniques (S/P); Room for the choice of a technique (S/P).	Diversity of any group of marine organisms makes checking compliance difficult (A); Unknown/ not specified organisms are left out.
Properties of Organisms			
Performance: Organisms larger than 250 µm must be removed with 99,9 % effectivity[16].	Water Quality: The number of organisms larger than 250 µm in the discharged BW may not exceed 1 organism per litre[17].	Strong link to techniques: enables choice by ship owner (S/P); Link to sampling and detection methods (A).	Less flexibility in techniques: Specifying properties means prescribing techniques based on these properties (S/P); Organisms vary in properties: Organisms outside the specified property range will be excluded (A).
Techniques			
Process: Ships should treat ballast water on board by means of a nano-filtration installation[20].		Clarity for the ship owner (S); Easy proof of compliance: checking the presence, state and operation of the installation (A).	Any number of techniques specified will exclude others (S/P); The link to actual introductions of species is diminished (A).

Combinations

To profit from the advantages of different types of standards, and take their disadvantages into account, combinations of the different types can be made. Neither types of standards, nor criteria exclude each other. In an overall standard one can for example specify water quality when possible or necessary (certain clear water routes, or high risk areas), and performance otherwise. Looking at the list of advantages and disadvantages, a good combination would be to combine a performance standard with a process standard. This would mean a two phased approach:

Performance: Installations or procedures are checked to determine their effective performance in different water types. If the performance is deemed sufficient, the installation is certified;

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[16] The reduction factor due to drinking water treatment (surface water to drinking water by UV irradiation) is in the range of 10^6 to 10^8 for bacteria. Drinking water treatment installations can not be transferred directly for BW treatment.

[17] Choice of figure is arbitrary, the reduction factor named in footnote 16 is equal to 99.9999% reduction to 99.999999%.

[18] See footnote 14

[19] See footnote 15

[20] This filtration technique is necessary for the smallest planktonic organisms.

Process: Once an installation or process is certified, it is placed on a list of prescribed ballast water management options (toolbox, see figure 5).

This type of approach combines the advantages of prescribing a performance, which provides a link to risk reduction, with clarity for ship owners, and ease of checking compliance.

Exemptions

In international shipping activities there is no such thing as a standard vessel. Vessels differ in many ways: from the cargo they carry, their layout, their size, their routes etc. The different ship types will differ in the applicability of ballast water management systems, costs of ballast water management options, but also in risk of transporting alien species.

These are two different reasons to propose differentiation: the first based on costs, the second based on risks. Based on economic criteria, aimed at preventing disproportionate claims on ship owners, a differentiation may be decided on between ships types and ships ages. The second reason, risk, follows the assumption that the risk differs per shipping route and season, and thus may require different approaches between geographical areas and seasons.

The range of available treatments and the need to differentiate between vessels is very dependent on the type of standards that will be chosen. A standard concerning procedural aspects of ballast water management may not need to recognise the difference between vessels. Most other forms of standards will however include some kind of differentiation of ship types, ages or geographical reference.

Ship Types: Differentiate or not? Differentiate to what criteria (size, engine space, ballast water capacity, design)? Who decides if any vessel meets the criteria?

Ship Ages (grandfather clause): Differentiate or not? Is retrofit necessary? What phasing? Based on what length of write off period (will differ per ship owner)? When should all vessels comply?

Geographical: Differentiate or not? Which routes are acceptable and which are not? What accepted criteria will be used? Can flag states deviate by imposing additional regulations (and how could these be incorporated in the standard)?

Seasonal: Differentiate or not? Which routes are acceptable in what season and which are not? What accepted criteria will be used (as above)?

Organisation / recommendation

At the moment we are at the beginning of the process of solving the ballast water problem. For this reason the organisational approach to a standard must be flexible. There must be clarity to ship owners and different governments.

The following approach could be considered: a committee (group of experts) is to be established under the authority of the IMO that would be responsible for the standard (see figure 5).

This committee can periodically review the standard based on new knowledge of the risks of introductions through ballast water and the state of the art of treatment technology.

The standard would not be part of a future ballast water convention, but would be referred to by such a regulation[21]. The standard would consist of a performance standard part, used to test promising techniques. Once a technique has been found to comply with the performance standard, it can be placed on a list of approved techniques: a flexible toolbox (process standard).

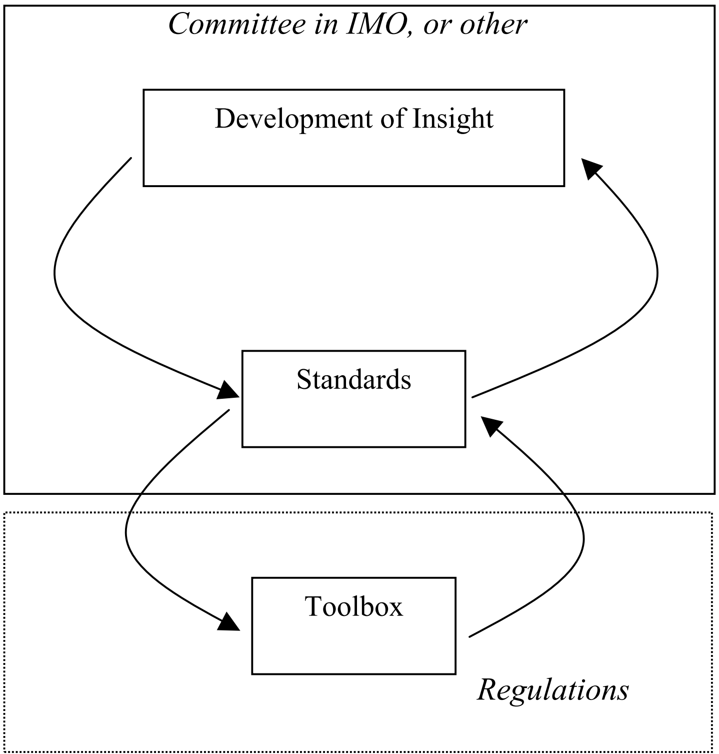

Figure 5: A committee manages and reviews a standard, techniques are placed in a toolbox, which is part of regulations for ballast water management

A thorough market analysis, linked to an assessment of introduction risks under different circumstances would reveal the current state of technology, and the way in which techniques can be used to reduce risks. The current conference is a good initiative to gain such an overview. The results from the analysis should be formulated into an overview for the MEPC, to indicate the effectiveness[22] of different techniques. Techniques can be placed on a scale ranging from cheap to complex/expensive. On the an other scale, different ballast water conditions can be described (turbid, containing sewage, brackish etc). The overview itself should provide insight the score of different techniques on an effectiveness criterion (% reduction of a certain size, % kill of a certain group).

Uncertainties at the moment of our study focus on the link of any treatment option to the risks of introduced species. Better research on how these mechanisms work can be a way to strengthen the knowledge of risk, and any decision based on the management of risks. In the meantime the uncertainties are great, but should not prevent the IMO from developing a standard which ensures maximum reduction of risk. This standard should provide an encouraging starting point for the development of new, innovative, and effective techniques

[21] Discussions focus on the choice of a new appendix under MARPOL 73/78, or a new Ballast Water Convention, in the first case provisions for periodic review should be made. At the moment the second option seems more likely.
[22] As far as known. If not yet well researched, this should be included into any recommendation as well.

Way ahead / conclusion

In this paper we have tried to show different aspects that may be taken into account when choosing an international standard on ballast water management. In the introduction we more or less promised to show the way ahead. Here we will try to show a process which could see to it that the missing parts of the discussion are addressed.

In general, when forming any standard, a set of steps of agreement should be taken systematically. As indicated in the introduction, we feel that different parties within the IMO are working at different steps in the process, and are therefore not coming as close to an agreement as possible.

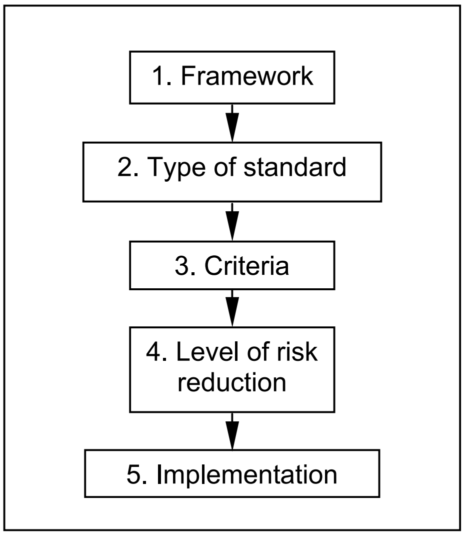

Figure 6: Possible steps toward a standard

We recommend the following steps to be taken in developing a standard:

1 Agreement on the framework of the standard

The agreement must address the relationship of the standard to a possible convention and establish the bodies responsible for the implementation of the standard. Organisations and procedures for the checking of compliance should be established. This means drawing out the responsibilities of flag, port and coastal states towards the legal instrument to be developed.

2 Agreement on the type of standard

A decision needs to be made on whether a management type standard or a technical standard will be implemented. If a technical standard is chosen weighing the advantages and disadvantages, will it be a process standard, a performance standard or a water quality standard?

3 Agreement on the criteria of the standard

If a technical standard is chosen, decide at what level the specification for a treatment option will be triggered. The logical link between risk reduction and the technology is most important and should always be kept under review. The choice between different endpoints should consider practical aspects as well as aspects that would enable an assessment of the risk reduction to be made.

4 Agreement on a level of risk reduction

Taking practical and economic limitations into account a choice on the level of risk reduction should be made. For a performance standard it should be recognised that techniques will differ in their performance under different application conditions. Equally, each level of risk reduction will generate a cost level and have associated advantages and disadvantages. The market supply of available techniques should also be taken into account when making these decisions.

5 Agreement on implementation

Implementation requires agreement on differentiation, authorities to check compliance, a time schedule, etc. At this stage consideration should also be given to an agreement on a periodical review and revision of the standard.

In the formation of the standard most of the above decisions are largely political in nature and it is important that they are not treated as purely technical.
The International Ballast Water Treatment Symposium could aid in showing the level of risk reduction that can be attained with the current state of the art of technologies. Here together at the workshop for standards, we could aid the MEPC by proposing a way through the above process.

Proposed Standards for Evaluating Ballast Water Treatment Options

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Abstract

The transfer of exotic species with ships ballast water has been the focus of many research projects in recent years. It has been demonstrated in numerous studies, that many organisms from different trophic levels can be found in ballast water tanks, ranging from vira to metazoa (including e.g. crabs, snails and fish) as well as algae and various resting stages (cysts). In the past decade, the main interest of these projects was the description of the status quo, regarding invasions of new species and the resulting problems, both ecologically and economically. In recent years, however, the focus of the research has changed to the development of practicable ballast water management strategies and various new treatment options. These include physical treatments such as heat and filtration as well as various chemical treatments with oxidising chemicals or biocides. An urgent need exists to develop agreed upon (minimum) standards to be met by applying a proposed ballast water treatment technique to enable accordingly a comparison and ranking of techniques. This contributions aims to support the development of such standards and further provides details on appropriate sampling techniques for compliance testing.

The treatment options are proposed to be divided in methods that remove organisms from the ballast water (physical treatment techniques, e.g. filter devices), and methods that treat, but do not remove organisms from the ballast water (e.g. chemical treatments). In order to compare the effectiveness of the proposed treatment methods, it is necessary to test all of the above methods with a standardised, appropriate testing procedure. This paper proposes specific testing standards for both, physical and chemical treatments, as well as an internationally accepted sampling standard for ballast water tanks, in order to evaluate the *in situ* results of ballast water treatments.

Standards for physical ballast water treatment methods

The distribution and density of marine fauna and flora is not the same everywhere. In a given geographic region some species may be more common than others. No marine species occur in all ocean waters. Even the most common and most widely distributed species are not found in comparable densities over their whole distribution area. A scattered distribution pattern is part of the biological characteristics of plankton organisms. The performance of the removal technique under consideration should be proven by using a test setting taking into account the natural variability of plankton organisms.

Regarding physical treatment options that remove organisms, the basic proposed idea is to define criteria, such as size limits of organisms above which these have to be removed to a certain percentage and by this to assess the removal performance of a specific treatment technique.

To compare the performance of different physical treatment options a standardized plankton community needs to be defined, as the natural occurrence of varying species diversities and densities of organisms makes it difficult to work with living organisms in the light to compare the performance of treatment techniques. Therefore, it is assumed that living plankton organisms cannot be used for this purpose and synthetic microspheres may be used in instead of living organisms. Microspheres made of synthetic material are available from 5 microns in diameter with different gravity. A proposal for an appropriate composition of microspheres was previously outlined in detail and consists of different size classes and numbers of synthetic microspheres (MEPC45/2/8, see below).

Although phytoplankton (microalgae) are very small, the majority of species are larger than 10 microns. Some microalgae species are even larger than 350 microns. Zooplankton organisms consist of a large number of taxa. About 8,500 species belong to the prevailing group of copepoda (free swimming, small crustacea). The body length of most species is between 500 to 2500 microns. Small size organisms (e.g. bacteria and viruses) may not be treated with species removal techniques. However, some bacteria (e.g. Cholera) use zooplankton organisms as hosts which can more easily be removed.

To prepare an appropriate mixture of microspheres to simulate a plankton community one needs to take into account that plankton organisms are of different body length and occur in highly varying densities. It is proposed to use the following mixture of microspheres for the approval purpose:

size class [micron]	number of microspheres [per litre]
10	100 000 – 1 000 000
25	10 000
50	5 000
100	1 000
500	100
1000	50
2500	5

The proposed performance criteria for removal techniques includes the removal of 95 percent of all organisms with a body length larger than 10 microns, and removal of 99 percent of all organisms with a body length larger 100 microns. It should be noted that treatment techniques that remove organisms from ballast water may be used as initial treatment to be followed by additional treatment systems, such as exposure to UV or chemical treatments, to inactivate the remaining load of organisms in the water.

Standards for chemical ballast water treatment methods

Chemical treatment options of ballast water have to be effective to eradicate the full range of organisms present in ballast water. Therefore, the effectiveness of new chemical treatment options has to be tested with organisms representing all of the trophic levels found in ballast water. This normally involves numerous experiments with individual species. This process is very time consuming, expensive and difficult to standardize.

A new benchmark-test was developed, taking into account the natural variability of plankton organisms and the species diversity (bacteriae, viruses, phytoplankton and zooplankton). It also accounts for the different sensitivities of the above organisms to chemical treatments and for different pathways of the chemical substances. The brine shrimp, *Artemia salina,* was chosen as indicator organism, because it is known to show a relatively low sensitivity to chemicals. This makes it a "worst case scenario" for chemical treatments as other organisms are less resistant to chemical treatments.
The life-cycle of *Artemia salina* is well understood (Fig. 1). The adults live in shallow sea water or rock pools. They produce eggs, that float in the water and may either develop directly into nauplii (larva) or, under unfavourable environmental conditions (drying out of rock pools), turn into resting stages that can survive long dry periods. When the environmental conditions improve, resting stages are "re-vitalised" and the nauplii hatch.

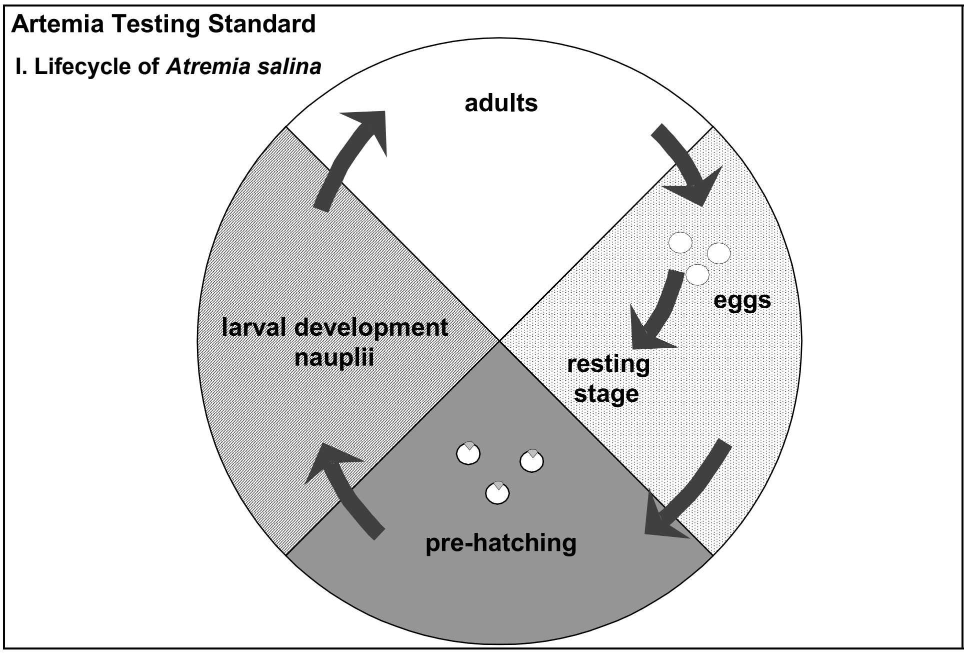

Figure 1: Life-cycle of *Artemia salina*.

Adults of *Artemia salina* are already used as indicator organisms in many standard tests. As a new development, the proposed test uses 4 different life-stages of *Artemia salina,* adults, cysts, developing eggs (prior to hatching) and nauplii, to account for most of the trophic levels of the organisms frequently found in ballast water tanks (see Tab. 1 and Fig 2).

The cysts of *Artemia salina* could be used as a model for the cysts of any species, where treatment chemicals would have to pass a thick shell to influence the organism. In addition, the developing eggs (prior to hatching), where the thick egg shell has burst open and the early life stage is only separated from the water with a thin membrane, could account for eggs of a number of different species and for some bacteria, where the chemical only has to pass through thin membranes.

After hatching, the nauplii of *Artemia salina* are fully exposed to the surrounding water (and chemicals), but they do not actively feed for the first three days. This development stage could be used as a model for the passage of the chemical through body surfaces of many organisms. The adult *Artemia*, however, actively feed on algae and have fully developed gills. They could be used a model for passage of chemicals through the food and / or through gills.

Table 1: Life-stages of the brine shrimp, *Artemia salina*, their trophic level and the different pathways of the chemical substances.

Artemia development stage	Trophic level	Pathway of chemical
Adult	Zooplankton, grazer	with food and/or over gills and body surface
Nauplii	larvae (not feeding)	over body surface, gills
Developing eggs	floating / demersal eggs	through egg membrane
Cysts	demersal / benthic cysts	through thick egg shell

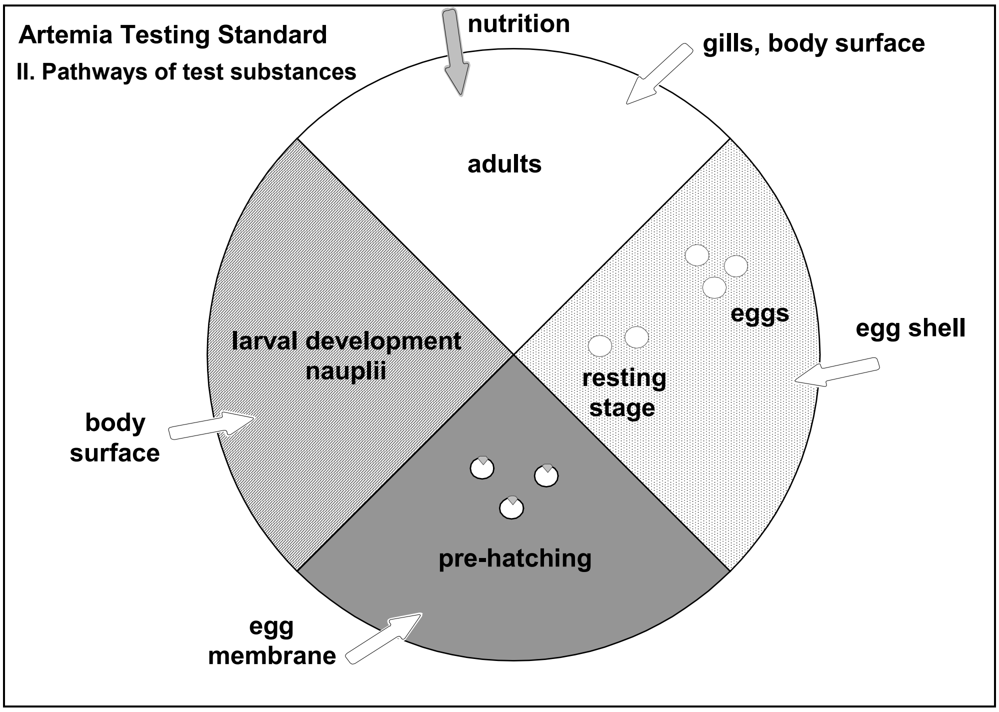

Figure 2: Pathways of test substances.

The effectiveness of the chemical treatment option is measured as mortality of the adults and the nauplii, and the hatching rate of cysts and developing eggs, respectively. The experimental design includes 13 separate measurements (after 1h, 3, 5, 7, 10, 12, 24, 30, 36, 48, 54, 60, 72 hrs exposition time) for each of the 4 development stages in three replicates and control experiments (without treatment).

The results of the tests will give a quick and efficient estimate of the efficacy of the proposed chemical treatment option, avoiding costly and time consuming multiple experiments and to minimise the number of necessary field experiments. The information gained from mortalities and hatching rates after different exposure times, allows the quick estimate of effective chemical dosing: over-dosing will result in very fast mortalities, while under-dosing will show slow or no moralities and unchanged hatching rates. Therefore, the best dosing of the test substance can be easily identified.

The *Artemia* Testing Standard has already been used in a national research project (Degussa AG unpub. data). The results indicate, that Peraclean® Ocean could be a very suitable oxidising chemical in ballast water treatment applications (Tab. 2), while a 25% solution of Glutaraldehyde (see Tab. 3) was not successful at the concentrations given in the literature[24].

[24] Lubomudrov, L.M., Moll, R.A. & Parsons, M.G. 1997. An evaluation of the feasibility and efficacy of biocide applications in controlling the release of nonindigenous aquatic species from ballast water. Unpub. report to the Michigan Department of Environmental Quality Office of the Great Lakes.

Table 2: Results of benchmark tests (ATS - *Artemia* Testing Standard) with Peraclean® Ocean (Degussa AG unpub. data). Experimental conditions: Salinity = 33 ppt (marine conditions), room temperature. Values in brackets represent the highest mortality reached at the end of the experiment.

Testorganism Brine shrimp, *Artemia salina*	Parameter observed	Concentration of Peraclean® Ocean (ppm)	Max. Hatching Rate after 72 hrs	Time (hrs.) needed to reach 100% Mortality
Cycts	Hatching rate Survival of Hatched Nauplii	350 700 1.400	3% 0% 0%	
Pre-incubated Eggs	Hatching rate Survival of Hatched Nauplii	350 700 1.400	9% 0% 0%	
Nauplii	Mortality	350 700 1.400		(97%) 36 8
Adults	Mortality	350 700 1.400		(38%) 12 8

Table 3: Results of benchmark tests (ATS - *Artemia* Testing Standard) with Glutaraldehyde (Degussa AG, unpub. data). Experimental conditions: Salinity = 33 ppt (marine conditions), room temperature. Values in brackets represent the highest mortality reached at the end of the experiment.

Testorganism Brine shrimp, Artemia salina	Parameter observed	Concentration of Glutaraldehyde (ppm)	Max. Hatching Rate after 72 hrs	Time (hrs.) needed to reach 100% Mortality
Cycts	Hatching rate Survival of Hatched Nauplii	25 69 138 276	32% 13% 12% 6%	
Pre-incubated Eggs	Hatching rate Survival of Hatched Nauplii	25 69 138 276	28% 9% 13% 5%	
Nauplii	Mortality	25 69 138 276		(5%) (5%) (3%) (5%)
Adults	Mortality	25 69 138 276		(3%) (2%) (8%) (7%)

Internationally accepted sampling standard for ballast water tanks

Intercalibration of ballast water tanks sampling techniques

During a European Union Concerted Action study on species introductions, an intercalibration workshop on ship ballast water sampling techniques considered various phytoplankton and zooplankton sampling methods. For the first time, all the techniques being in use world-wide were compared using a plankton tower as a model ballast tank for zooplankton while phytoplankton samples were taken simultaneously in the field. Net designs varied greatly with three cone shaped and eleven non-cone nets being employed while net lengths varied from 50 to 300 cm., diameters from 9.7 to 50 cm. and mesh sizes ranged from 10 to 100 µm. As anticipated, the results of this workshop did not lead simply to one finally recommended sampling technique, several methods proved to be valid elements of a hypothetical "tool box" of ship sampling techniques.

Phytoplankton

In total 9 different phytoplankton sampling methods (5 nets, 3 pumps and a Ruttner bottle) were simultaneously employed taking five replicates. Since the phytoplankton alga *Coscinodiscus wailesii* was present in every sample and since the species was large enough to be representatively sampled by all test sampling gear this species was chosen for a quantitative evaluation of abundance retrieved by the various sampling methods. It was agreed that the best method should be the method sampling the highest number of *C. wailesii* with the smallest standard deviation.

Zooplankton

Zooplankton sampling methods were compared by sampling a plankton tower of 5.3 m³ capacity. The tower was filled with sea water and served as model ballast tank. *Artemia salina* nauplii (340 µm averaged length) and *Crassostrea gigas* larvae (90-100 µm diameter) were used as test organisms. In total 16 different zooplankton sampling methods previously used during shipping studies were employed carrying out four replicates for each method. The order of the methods applied to the plankton tower was strictly the same during all replicate sampling trials, starting with the net filtering the smallest volume of water; thereby minimizing density depletion of spiked specimens.

Results and discussion of sampling methods

A wealth of literature on sampling efficiency of various plankton nets used in limnic and marine field studies exists. Most of these are towed horizontally at relatively high speed. With regard to this exercise the phytoplankton sampling, being undertaken in the harbour basin rather than in a ballast tank, is largely comparable to the above mentioned vertical net tows. However, comparisons between field sampling and sampling onboard ships are difficult as there are many technical restrictions in ballast tanks which are never encountered in open waters. Ballast tank configurations only enable vertical net tows. Therefore, for the purpose of this study, we restrict the discussion on a comparative analysis within the given technical scenario.

In routine ballast tank studies a number of logistical and technical considerations will determine which sampling technique may be used on board. There are technical limitations such as access to the water via sounding pipes and manholes, tank depth, manhole diameter and design of internal support frame structure within ballast tanks. Ease of handling will be as important as the quality characteristics of the method employed to choose the appropriate technique for given scenario on board ships. Therefore a selection scheme has been developed, based on the overall results of the intercalibration exercise (see Fig. 3).

The first criterion to be considered is access to the ballast tanks; this will depend largely on ship and tank design and, in general, direct access to ballast tanks via tank openings (manholes) is the recommended access for sampling. The objectives of sampling (e.g. qualitative or quantitative samples, target organisms or all taxa) are other criteria for method selection. The sampling of ballast water tanks via opened manholes would usually require short nets because they are more easily manipulated and because the configuration of ballast tanks often restrict the depth of sampling tows. Cone nets become an ideal way of easily and efficiently sampling a ballast tank. The main reason for the high efficiency of the cone net would be that this particular net configuration increases the filtration efficiency by limiting the overflowing of water through the opening caused by the resistance of the mesh within the net.

Phytoplankton

For phytoplankton sampling nets, it is recommended that relatively small mesh-sizes (e.g. 10 µm) be used. Larger mesh sizes will exclude smaller species and may result in lower species richness estimates. However, fine mesh nets may clog quickly if organisms are very abundant, so a degree of compromise may be required. The relevant characteristics for the recommended equipment to sample phytoplankton can be summarized as follows:

(i) The Waterra pump, operated via sounding pipes, was the best pump in the qualitative sampling trial. It was the only sampling technique able to sample water from the bottom of deep tanks e.g. double bottom tanks. However, restrictions in its use include the provision of a power supply (not always available on board or not permitted to use).

(ii) The small hand pump, operated via sounding pipes, was the second best method for qualitative sampling. The pump is lightweight, easy to use and can sample depths down to approximately 8 m.

(iii) The Monopump, operated via sounding pipes and manholes, proved to be the most effective method for quantitative sampling however, it was heavy and cumbersome to use. The sampling depth is > 15 m.

(iv) The small cone-shaped net (meshsize 10 µm), operated via manholes, was the best overall method in the qualitative sampling in the trial.

(v) The Ruttner water sampler, operated via manholes, showed similar quantitative effectiveness to the Monopump but is able to sample water from greater depths and is lightweight in comparison. As a further advantage, the sample does not need to pass through a plankton net or pump, resulting in less damage to any organisms retained.

Zooplankton

The variability of the data are high, possibly as a result of a patchy distribution of test organisms in the plankton tower. Tentative overall performance evaluations can be given, focusing on practical criteria such as ease of handling and access for sampling in ballast tanks. In zooplankton studies, nets with mesh size of 55 µm will capture the youngest stages of Mollusca and Crustacea as well as many of the other taxonomic groups commonly found in ballast water. Smaller mesh sizes are not recommended, as nets easily become clogged with organisms. The following sampling techniques can be recommended for zooplankton recovery in ballast tanks and may be considered to become common options within the "tool box" of sampling methods:

(i) The small cone-shaped net (meshsize 55 µm), operated via manholes, was the most effective of all methods in the quantitative sampling trial. The relatively short net is unlikely to become stuck in ballast tanks (length < 1 m) while easy handling is achieved due to valve equipped, filtering cod-end.

(ii) The Waterra pump, operated via sounding pipes, exhibited similar quantitative effectiveness to the small cone-shaped net, however, a power supply is needed to operate the pump and this may be difficult in some situations. It is the only method capable of sampling water from the bottom of deep tanks e.g. double bottom tanks.

(iii) The small hand pump, operated via sounding pipes and manholes, was the best manual pump of all quantitative methods tried here. This pump is easy to use, comparatively lightweight and therefore easy to transport and handle. The maximum sampling depth is less than 8 m.

(iv) The Monopump, operated via sounding pipes and manholes, is recommended if the required sampling depth is greater than 8 m and if the Waterra pump cannot be used due to the lack of power supply.

(v) The large cone-shaped net, operated via manholes, was the second most effective net method in the quantitative sampling trial however, the relatively long net may easily become stuck in ballast tanks (length > 2 m). Simplified sample handling is available because of the valve equipped, filtering cod-end.

Recommended sampling design

The preferred access to ballast tanks for quantitative sampling is via opened manholes. This would normally result in the use of short nets, which are more easily manipulated and can be operated in ballast tanks which often restrict the depth of sampling tows. As a result, cone nets may be regarded as a suitable way of easily and efficiently sampling a ballast tank. The main reason for this high efficiency is the particular net configuration that increases the filtration rate by limiting the overflow of water from the net caused by mesh resistance. It was seen that nets exhibited consistently low sampling efficiency when the design included a high canvas area relative to the filtration area also, the design of some cod-ends contributed to this reduction. Certain net designs incorporate a sample bottle that can be attached to, and removed from, an internal fitting in the net. In these cases, a thicker, stronger layer of net or canvas wrapped around the fitting is often attached. This area may trap water and so result in organisms being excluded from the sample while further problems may arise from repeated mesh rinsing after the sample has been collected.

It is recommended that the cod end of a net should be made of a cup with filtration panels on its side and a tap at the base of the cup. If the cod end is metallic, no additional weighting is required to sink the net and this will reduce the risk of entanglement in structures in the ships ballast tanks.

A major outcome of this exercise was the clear requirement for flexibility when sampling ships' ballast water. Different situations require different solutions, and much will depend on the specific requirements of particular studies. The subsequent choice of methods will be based on the qualitative or quantitative objectives of the study, for which the intercalibration data provided the best recommended method. The exercise demonstrated the high variability between and within methods and the virtual impossibility of obtaining a complete representation of the taxa that are present in ballast tanks. Full recovery of organisms contained in ballast tanks may remain impossible, but it is possible to strive for representative target plankton taxa for ease of comparison between studies. Larger organisms may also be sampled by the use of different collecting methods, such as light traps or baited traps.

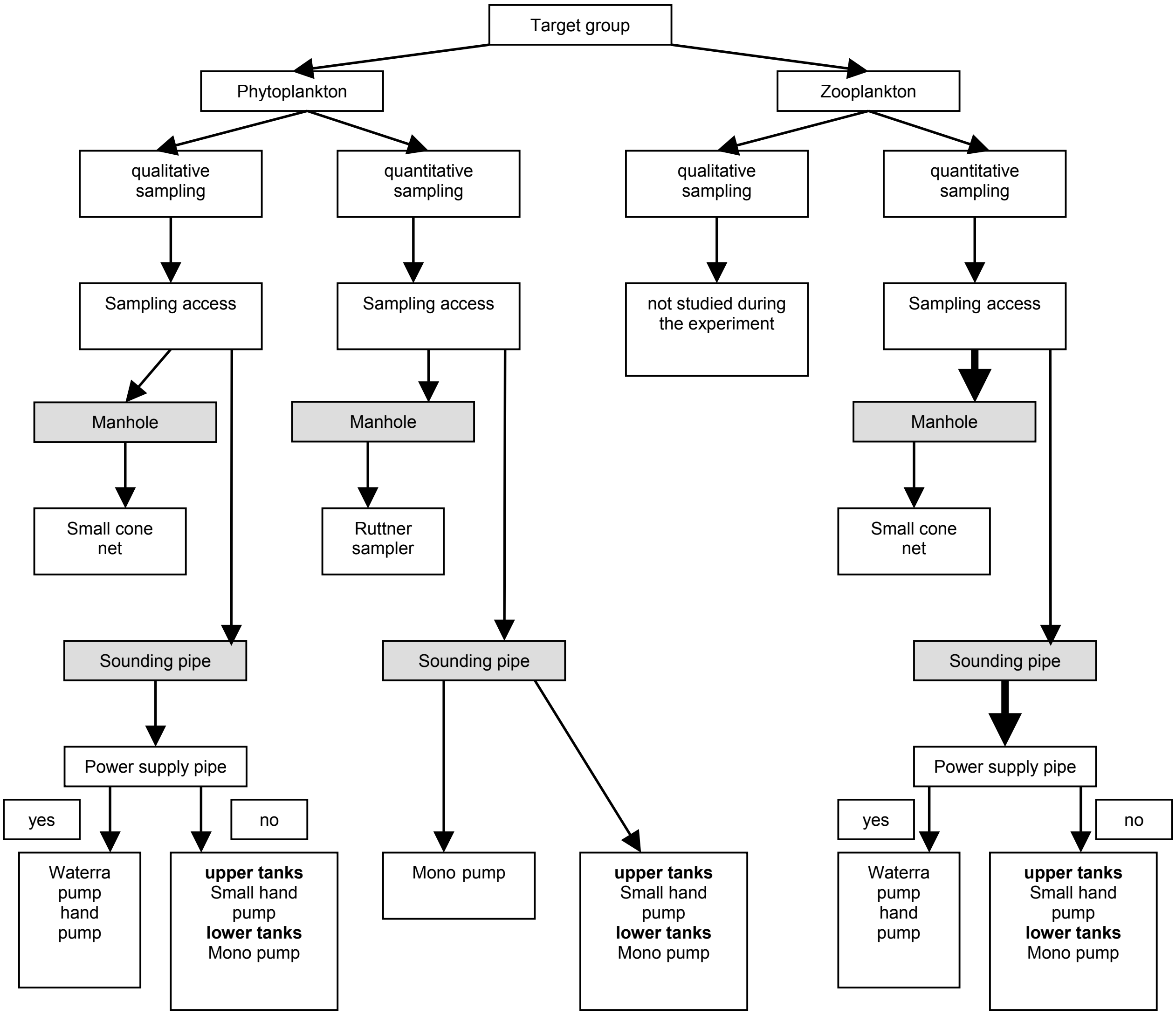

Fig 3: The choice of the methods recommended according to biological target groups, mode of sampling (quantitative and qualitative sampling) and sampling access.

Methodical Approach to Develop Standards for Assessment of Harmful Aquatic Organisms in Ballast Water

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Abstract

This paper presents a methodical approach that can be adopted for the identification and the development of ballast water and ballast water treatment standards. The proposed principles can be used to assess the effect of any category of treatment options or methods (or combination of methods) that are currently in use or under development independently of the functional nature of the methods. It will also be suitable as a conceptual compliance mechanism for alternative treatment methods, and to validate or refine treatment methods during development.

The proposed approach is flexible and can be adapted to meet different requirements as reflected by the 2-tier approach and differentiation between new and existing tonnage.

Introduction

Recently, substantial progress has been made within MEPC on several elements and issues of a draft convention for the control and management of ships' ballast water and sediments. The agreement on a standard for assessment of whether the effect of ballast water treatment method(s) are satisfactory in removing harmful aquatic organisms and pathogens is currently one of the principal outstanding issues in the development of a successful international ballast water management system.
There is therefore a recognised need for the development of a standard test regime and some generally accepted criteria against which all treatment methods, or combination of methods (chemical, biological, mechanical, physical or others) can be tested in order to achieve acceptance. Such a test regime should also be suitable for verification of the effect of selected treatment methods in operation.

The aim of this paper is to present a methodological approach that;

- can help provide definition criteria for ballast water standards or norms
- is suitable for the assessment of ballast water treatment methods standard(s) and does not eliminate methods of treatment.

Background

The challenge

A pure qualitative definition of a global acceptable standard for a "cargo" of ballast water to meet, may not be possible nor feasible to reach. However, what seem to be of a general acceptance is that some form of treatment of ballast water is required at least for a number of ballast voyages (hence the standard of the "donor" water may not *comply* to the standard of the "recipient"). Based on this, the approach of establishing some form of control regime may start by assessing the possibility of establishing criteria (and methods) for comparing the quality and efficiency of treatment options reflecting the characteristics of the respective options. This approach may form a platform enabling us to define overlaying norms in order to control ballast water quality.

The assessment of a specific treatment option must include a number of items:

- implications affecting the vessel
- implications of occupational nature
- implications to the environment
- efficiency and reliability as a countermeasure against unwanted harmful transfer of aquatic organisms

This proposal only cater for the latter of the above issues.

There are various approaches that can be selected to assess the effect of a ballast water treatment method against some identified criteria.

It might for example be considered necessary to perform extensive sampling before and after treatment. The sampling would then be followed by detailed biological analysis of the samples to identify the presence of potentially harmful organisms both before and after treatment. To enable an assessment of the efficiency of the treatment method and a comparison with other treatment methods, the reduction in the presence of potentially harmful organisms would have to be expressed quantitatively, for example as a density reduction.

The main problem with this approach is that the required biological analysis is very laborious and time consuming. Due to the natural variation, several biological samples will need to be analysed to assure that the result is representative for the investigated ballast tank(s).
This method will therefore not be practical for the comparison of a large number of treatment methods or a combination of treatment methods. This type of methodology will also be too time consuming to be practical for analysis of ballast water from vessels prior to treatment (e.g. de-ballasting or other).

To obtain a generally accepted standard suitable for comparison of different treatment methods, a common biological basis need to be developed.

The selected methodological approach

The principles for testing of ecological toxicity are generally accepted and widely applied for assessing the impact on living organisms of exposure to a substance.

These principles are also suitable for assessment of other impacts of a biological or physical nature, e.g. relating to the effect of treatment of ballast water. Toxicity testing is most commonly applied to assess the quality of the environment (e.g. pollution level) or to establish criteria to reduce the risk of causing harm to living organisms. When applying these principles to the ballast water issue, the approach is reversed. The objective is to identify criteria enabling reliable and consistent assessment of the efficiency of various ballast water treatment methods. This way the goal of preventing ballast water organisms from establishing and/or reproducing in a ballast water recipient port can be reached.

Outline of suggested methodology

Use of representative biological organisms

It is suggested that representative biological organisms can be determined by defining groups of organisms. Acceptance levels, for which treatment methods have to comply, can then be developed for each organism group. Hereafter, the chosen organism group is referred to as a ***model group***.

To represent criteria which prevent ballast water organisms from establishing and/or reproducing in a ballast water recipient port, the *model groups* have to meet a range of criteria, and it is anticipated that all *model group* species will be robust, and that the most resistant species and life stages will be highly represented.

The purpose of each selected organism groups is to serve as a model for one group of organisms reflecting how this group resists ballast water treatment. This does not necessarily require a typical ballast water organism. Ballast water treatment systems can be assessed both through pilot-scale (0.1-10 m^3 water) and full-scale tests.

Selection of model groups

Selection of representative species for each *model group* and number of *model groups* required should be done reflecting the different groups of marine organisms. The selected species must be well described and specified with respect to both species and strain. The cultivation conditions prior to the test as well as the method for assessing viability has to be clearly defined. The selected organisms should be easy to cultivate and handle; *i.e*. they must be robust. They should be non-pathogenic and preferably belong to species with a fairly global distribution. The organisms must be readily available from culture collection. The number of different *model groups* should be limited to a manageable number of organisms. Each organism should be assessed for the purpose of representing ballast water species.

Table 1 gives a starting point for the process required to select suitable model groups and representative test organisms. The selection of model groups and test species, and the determination of the required number of test species will require further consideration. Important biological properties of species commonly found on specific Hazard Species Lists and Target Lists (lists of defined unwanted species) should be represented by the selected test species and will therefore need to be assessed in this process.

Table 1: Possible model groups and examples of some suitable test species representing these groups.

Model Group	Sub groups (systematic group)	Test Species
Phytoplankton	Dinoflagellates	
	Diatoms	*Skeletonema costatum, Phaeo-dactylum tricornutum*
Crustaceans	Crabs	
	Shrimp	*Artemia salinas*
	Copepods	*Acartia tonsa*
	Amphipods	*Corophium volutator*
Rotifers		*Brachionus plicatilis*
Polycaetes		
Molluscs	Mussels	
	Gastropods	
Fishes		Turbot (*Scophtal-mus maximus*)
Echinoderms		
Ctenophores		
Coelenterates		
Bacteria		*Vibrio fischeri*
Viruses		

Use of biosensors as model groups

Use of biosensors for environmental monitoring has recently gained considerable international attention due to the recognition of their qualities of rapidity, low cost, portability, ease of handling, environmental relevance, and reproducibility of results. Biosensors are often used to provide a rapid assessment of biological toxicity, for example of offshore chemicals.

The biosensor technology

Biosensors utilise bioluminescence, which is a natural characteristic of some bacteria. One of the best known naturally bioluminescent bacteria is the marine bacteria *Vibrio fischeri*, commonly known as *Photobacterium phosphoreum*, as used in the commercially available Microtox test.
Biosensor technology can be utilised by selecting biosensor bacteria representing relevant ballast water species or ballast water *model groups*.

If the selected bacteria are not naturally bioluminescent, they can be modified by insertion of reporter genes, for example the *lux*-genes, which are responsible for bioluminescence. The metabolic status of these bacteria can be measured as a change in bioluminescence, i.e. the degree of light loss indicates metabolic inhibition of the test organism. This can be measured in a simple, rapid luminometric test assay providing a reliable and rapid environmental risk assessment.

It is therefore proposed to use biosensor *model groups*, either as a standalone tool, or as a supplement to the *model group* approach outlined in **Table 1** in the development of standards for assessment of harmful aquatic organisms in ballast water.

Eco-toxicity

The suggested approach is based on the basic principles that are widely applied in eco-toxicity testing. An acceptance criteria profile can be established based on an allowable level of the selected *model groups*. This allowable level can be expressed as a *model group* concentration or a total quantity (e.g. expected number of individuals) in the ballast water tank. The aim is to develop a test that is suitable to assess whether various treatments successfully reduce the number of specimens in the defined *model groups* to an acceptable level.

The effect of introduced or proposed treatment measures can then be considered against each *model group* by provision of a treatment impact profile. For the treatment measure to be fully in compliance, the treatment impact profile must satisfy the acceptance criteria profile for all *model groups*. The principle is illustrated in Figure 1.

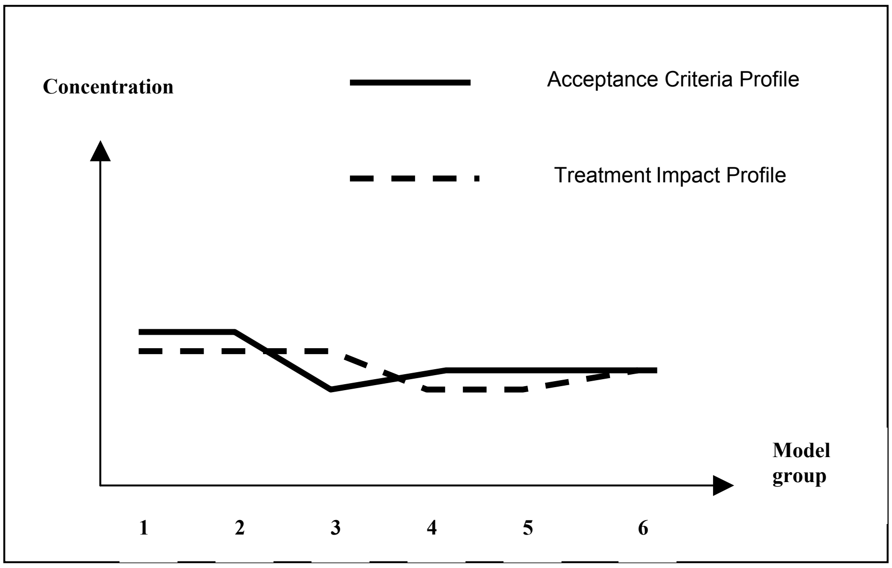

Figure 1. Hypothetical results for testing of a treatment method.

Development of acceptance criteria

A standard for assessment of ballast water treatment methods need to be founded on a set of clear, well defined and (preferably) widely agreed acceptance criteria.

The acceptance criteria may be related to the mortality rate following treatment e.g. concentration of living representative species in the different *model groups*. An introduced or proposed treatment method will be assigned a treatment impact profile with reference to application details (e.g. dose-response relationships) for the representative species. Critical factors may be whether one representative species can be selected for testing for each model group, or whether a number of species has to be selected to obtain satisfactory test results.

The requirement for safety factors in the acceptance criteria needs to be further evaluated as part of the work required to develop commonly agreed acceptance criteria.

Discussion

The use of *model groups* outlined in this paper can provide the basis for the selection of a standardised approach to assess the efficiency of proposed ballast water treatment methodologies. Although this approach is far less labour intensive than a full biological assessment of the actual ballast water, the testing of the effect of a treatment method on the survivability of species from all model groups mentioned in **Table 1** will still be an extensive, laborious and time consuming process. Further work to select suitable test organisms, and to minimise the number of different test organism species will therefore be important. The final selection of *model groups* and test organisms should be based on international consensus.

The presented *model group* approach will require calibration against general biological data and defined hazard species. Further work will be required to standardise ballast water sampling methods to enable efficient and consistent utilisation of the proposed methodology for testing of ballast tanks.

It is known that bacteria respond to most chemicals through mechanisms similar to those of higher organisms. Testing of the effect of ballast water treatment methods by using simple organisms like bacteria can therefore provide a fast, less complicated and far less expensive testing regime. This also means that it will be possible to perform a much higher number of tests.

It is therefore suggested that microbial biosensors are selected as a test organism. Microbial biosensors can, if required, be genetically modified to represent selected groups of hazard organisms. This approach will provide a rapid, low cost methodology with reproducible results suitable for testing and verification of the effect of various transfer prevention techniques.

The proposed *model group* approach can be developed into a set of standard tests to determine the efficiency of proposed risk reducing measures for different groups of hazardous species.

The methodology might also be used as a verification tool to test whether applied reducing measure(s) have the expected effect before a vessel with ballast water from a "high risk area" is allowed to de-ballast. The methodology can be used to express expected survivability of defined harmful aquatic species.

To summarise, the methodology will, when fully developed be suitable for:

1. General testing and verification of the efficiency of new ballast water treatment methods.
2. Spot tests on vessels' ballast water tanks to screen for harmful aquatic species.
3. Verification of the efficiency of a treatment method for single transfers, vessels or ballast tanks.
4. Screening to determine whether a vessel should be allowed to de-ballast.

Significant further work will be required in the process required to detail the proposed approach and to develop and fully test the biological basis for the selection of model groups and test species.

Possible Ballast Water Treatment Standards: USCG Activities

Richard A. Everett

Environmental Standards Division,
U. S. Coast Guard, USA.

Overview of USCG Program

Regulations

- Great Lakes and Hudson River
- National

Key activities

- Maintain the National Ballast Water Information Clearinghouse to monitor BWM, technology, and invasions
- Develop performance standards for BWM options
- Facilitate testing and evaluation of promising technologies

US Coast Guard Report to Congress

- Due between July 1, 2000 and January 1, 2002
- Assessment compliance
- Reporting requirement
- Voluntary guidelines
- Assess the effectiveness of voluntary guidelines in reducing the introduction and spread of ANS.
- Determination on need to make the voluntary guidelines mandatory?

Web sites for full first-year report

- National Ballast Water Clearinghouse
  http://invasions.si.edu/ballast.htm
- United States Coast Guard Ballast Management Program
  http://www.uscg.mil/hq/g-m/mso4/contents.htm

Practices and technologies for preventing introductions

- Many approaches under investigation
- Exchange
- Filtration/separation
- Physical & chemical biocides
- Lack of standards widely viewed as an impediment

USCG efforts to develop practical and effective treatment options

- Assess the status of treatment systems and processes
- Develop improved method for verifying exchange
- Develop standards & testing protocols
- Develop verification program
- Characterize NOBOB problem
- Facilitate opportunities to test treatment systems onboard vessels

Assess the status of treatment systems and processes

- Scientific audits
- Process testing

Scientific audits

- Evaluate test plans and methods
- Not an independent test or verification
- Four audits initiated
    - Two completed
    - One pending
    - One terminated by vendor

Scientific audits – present status

In Progress, with concerns identified as:
- Replication
- Pseudo-replication
- Quantification of condition variables
- Biological context

Report due in late summer.

Process testing

- Ballast Water Treatment Test Facility
    - University of Miami, Rosenstiel School of Marine & Atmospheric Sciences
    - Dr. Thomas Waite
- Ultra-sound treatment system
    - Oceanit Laboratories, Hawaii
    - Dr. Christopher Sulivan
    - SBIR exploratory project

Verification of mid-ocean exchange

- Currently, salinity is used.
- USCG and SERC investigating a multi-variate approach
- Expert-panel developed protocols
    - Metals
    - Turbidity
    - DOM
    - Radium
    - Phytoplankton salinity tolerance
    - Lignin

- SERC conducting field tests
  - Kate Murphy

Standards and testing protocols

Currently gathering information:

- ANSTF Ballast Water & Shipping Committee
- Globallast Symposium and Workshop
- USCG Standards Workshops
- Audit results
- Environmental Technology Verification Program

ANSTF Ballast Water & Shipping Committee

Options for treatment standards:

- Approaches based on exchange (per NISA)
  - Theoretical effectiveness (100% ER / 95% FT)
  - Measured effectiveness
- Approaches not based on exchange
  - Effectiveness of best available technology
  - Biological requirements of receiving ecosystem

Request for comment pending in Federal Register.

Issues regarding standards (BW&S Committee)

Nature and Implementation:

- Criteria for quantifying effectiveness
- Scales of determination
- Concentration vs percent inactivation / removal
- Existing vs future vessels
- Details and schedule for refinement
- Indicators for characterizing effectiveness

Included in FR Notice

USCG Standards Workshops

- Two independent meetings
  - April, 2001 Mystic, CT
  - May, 2001 Oakland, CA
- Expert panels
  - Ballast water biota and chemistry
  - Ballast water treatment
  - Water treatment
- Recommend:
  - Draft standard(?)
  - Testing protocols
  - Research needs

BWT Technology Verification Program

EPA Environmental Technology Verification Program:

- Collaboration (MOA pending)
  - EPA
  - USCG
  - NSF Int'l
- Independent verification of system capabilities

ETV objectives

- Accelerate development & commercialization
- Verify performance characteristics of market-ready technologies
  - Objective and quality-assured data
  - Independent and credible assessment

ETV values

- Fairness
  - To all participants
- Credibility
  - Of all information
- Transparency
  - Of operation and outcome
- Quality assurance
  - Throughout all activities

ETV process

- Operational criteria
  - Market-ready technologies
  - Independent third party testing
  - Public test plans, protocols, & reports
  - Quality management plans
- Stakeholder Advisory Groups
  - Identify important issues and parameters
- Technical Advisory Panels
  - Develop test protocols and plans
- Rapid availability of information
  - Reports
  - Verification statements

NOBOB problem

- >75% of the vessels entering the Great Lakes since 1993 are NOBOBs
- Residual ballast
  - averages about 158,000 L
  - consists of water and sediment
  - may contain between 106 – 108 zooplankton (MacIsaac, Robbins & Lewis, 2001)

USCG activity

- Collaboration
  - NOAA Great Lakes Environmental Research Laboratory (GLERL), Cooperative Research Institutes, EPA, & GLPF

- Characterize for the Great Lakes:
  - Temporal & spatial shipping patterns
  - Amounts of water and sediment
  - Biological composition & phys/chem conditions
- Assess:
  - Management practices employed
  - Efficiency and effectiveness of exchange in reducing introductions

Facilitate onboard testing

- Uncertainty about eventual standards perceived to limit opportunities for shipboard testing
- Vessel owners reluctant to commit resources
- USCG considering a program for approving systems for experimental installation

Experimental approval process

Details to be determined:

- Request for comment on concept pending publication in the Federal Register
- Likely to include:
  - Rigorous peer-review of preliminary results and proposed study plan
  - Limited time-span for approved status
  - Reporting requirement

More Information?

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