Ballast Water Management Technology Research

Seminar on Ballast Water Management
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Content of presentation

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- Challenges for treatment technology
- Laboratory testing
- Onshore and full-scale testing
- Upscaling the technology
- Cost evaluation
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Background

- Four greatest threats to the world's oceans
  - Introduction of invasive marine species into new environments through ships' ballast water, attached to ships' hulls and via other vectors
  - land-based sources of marine pollution
  - overexploitation of living marine resources and
  - physical alteration/destruction of marine habitat

Requirements for Ballast Water Treatment Technologies

- safety considerations relating to the ship and the crew
- environmental acceptability, i.e., not causing more or greater environmental impacts than they solve
- practicability, i.e., compatibility with ship design and operations
- cost effectiveness
- biological effectiveness in terms of removing, or otherwise rendering not viable, harmful aquatic organisms and pathogens in ballast water

Challenges for analysing technology

- Article 9 of the Convention states that "time required to analyse the samples shall not be used as a basis for unduly delaying the operation, movement or depature of the ship"
- At the moment, sampling and analysing of ballast water samples very laborious and time consuming
- Development of new methods for assessing viability of organisms essential in order to enable rapid, accurate and undisputable results

Potential BWM technologies identified for IMO MEPC 53 by U.S.

Manufacturer	Technology
Alfa Laval & BenRad, Sweden	Filtration + AOT (Advanced Oxidation Technology)
Alan Taylor & Associates, Australia	Heat treatment
Browning Transport Management "Aquahabistat" (AHS), USA	De-oxygenation
Ecochlor Inc., USA	Chemical disinfection
Environmental Technologies Inc., USA	Filtration + sonic radiation
Hamann New Modular BWM Systems, Germany	Hydrocyclon separation + chemical disinfection
Hyde Marine Inc., USA	Filtration + UV
Marenco Group, USA	Filtration + UV
Marine Technology Institute Co., Japan	Physical disruption/killing
MEPI, USA	Filtration, Bromine and Oxidation
NEI Treatment Systems, LLC, USA	De-oxygenation
Nutech O3 Inc., USA	Ozone
OptiMarin AS., Norway	Hydrocyclon separation + UV

Combined Uv and Ozone test system(left), Ozone (right)

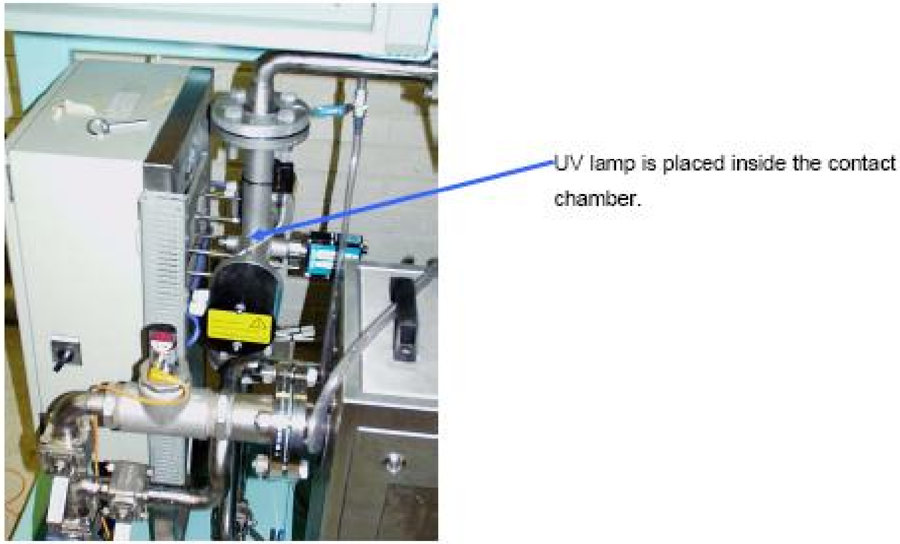


Figure 2. Ultraviolet light device in the test rig.

Onshore Tests

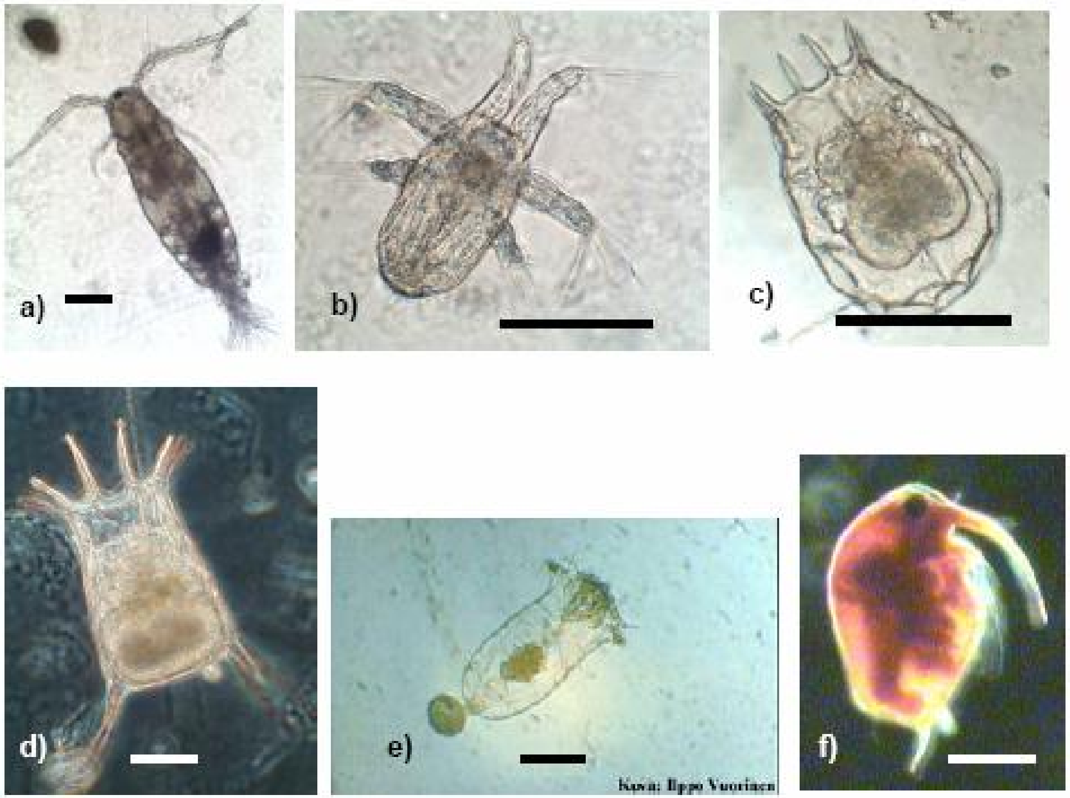


Figure 5. a) Acartia bifilosa male b) A. bifilosa nauplius c) Keratella cruciformis var. eichwaldivar. eichwaldi d) K. quadrata var. platei e) Synchaeta baltica f) Bosmina longispina maritima. Scale bar indicates 100 µm. Photos a)–d) by Sari Lehtinen, e) Ilppo Vuorinen, f) Satu Viitasalo.

Onshore results, I/III

- The results, with considerable reliability for UV treatment, were a 94.99% kill rates for copepods, 78.100% for copepods nauplii and 98.100% for rotifers. For the US technology, the mortality rates achieved were 94.99% for copepods, 86.99% for copepod nauplii, 95.98% for cladocerans, 80% for rotifers and 97% for barnacle nauplii.
- For the combination of US and UV, the mortality rates were between 97.100% and the combination of UV and hydrogen peroxide achieved mortality rates of 94.100%.

Onshore results, II/III

- The results, with considerable reliability for ozone treatment, with ozone dosage of 17 mg/L were 96.100% for copepods, 98.100% for copepod nauplii and 99.100% for rotifers. When ozone dosage was 7 mg/l, the results were 95.100% for copepods, 96.100% for copepod nauplii, 97.100% for rotifers and 99.100% for barnacle nauplii.
- The volume of the contact tank was 60 l for the ozone dosage of 17 mg/l and 360 l for a dosage of 7 mg/l. The ozone dosages were kept constant throughout the trials.

Onshore results, III/III

- The onshore test trials confirmed that all devices were working as they were designed and also most of the sources of error that occurred during the laboratory test trials could be reduced.
- The results were relatively reliable due to the adequate number of replicates and provided a basis for the up-scaling of the UV, US and ozone treatment processes.

Upscaling of the ultraviolet light, ultrasound and ozone technologies

- Ballast water circulation:
  If the ballast water is required to be treated during ballasting or deballasting with flow rates as high as around 5,000 m3/h, the required capital costs for US and UV units would be extremely high.
- Therefore, the possibility for ballast water circulation would
- enable a cost-effective design and use of US and UV treatment options. The potential benefits would be:
- **− less floor space required for one unit**
- **− more flexible installations due to smaller treatment units**
- **− lower power requirements**
- **− lower investment and operational costs**
- **− better utilisation rate and payback time for the investment.**

Contact Tank Approach

A treatment option based on ozone disinfection (or other options based on a long contact time) will expose all of the ballast water tanks to potentially harmful impacts.

- Therefore, all of the ballast tanks must be equipped with a pipeline network for ozone injection and also with adequate alarm and corrosion monitoring devices.
- Rather, two ballast tanks would serve as contact tanks for ozone and ballast water would be circulated from the ballast tank to the contact tank and back to the ballast tank. The potential advantages that could be achieved are a reduced need for additional piping and control and safety monitor systems, and reduced corrosion risks in other ballast tanks.
- More studies needed !!

UV technology

- ***General requirements for UV device***
- Based on the results and conclusion presented in Gloster-Herbert (2002), a UV treatment system designed for 90% transmittance should be able to deliver the following performance:

- - reduce bacteria by 90%
- - reduce the MS-2 coliphage virus by > 90%
- - reduce phytoplankton growth potential (chlorophyll *a* concentrations) by > 50%, but without 100% mortality, some phytoplankton survives with the capability to reproduce, though at slower rates. Holding the phytoplankton in dark tanks seems to increase the mortality rates.

UV technology

- ***General requirements for UV device***
- reduce the concentration of live zooplankton relative to the control, especially if treated during ballasting and deballasting. Zooplankton is weakened by the first treatment, continues to die off in the BW tank and suffers the greatest kill or removal rate on discharge. More die off after the discharge due to latent damage.

- - with combined cyclonic separation + UV and treatment during ballasting and deballasting, 90% reduction in live zooplankton density should expected (based on results from *Princess Regal* experiments).

Some UV advantages I/II

- UV has potential to be effective against all target organisms. It may be possible to increase irradiation intensities to address turbid water conditions. For varying turbidity and transmission levels, the optional automatic control of bulb intensity or ballast water flow rate could be provided.
- - UV has a long history in the marine industry and demonstrated low maintenance requirements.
- - New development in UV unit design with multiple lamps in cross-flow configurations shows potential advantages.

Some UV advantages II/II

- The basic technology is readily available for both low and high flow rates. Even for high flow rates (3,000 m3/h), the physical size is reasonable (around 4 m long, 2 m in diameter).
- - UV enables treatment during both ballasting and deballasting.
- - UV creates only a small pressure drop and requires simply piping connections.
- - UV is capable of automatic operation with electronic monitoring and alarms.
- - UV light does not change the physical characteristics of the treated water and is environmentally friendly with no known toxic by-products, residuals or lasting effects

US Technology I/II

- US devices generate high frequency energy that causes the exposed liquid to vibrate producing physical and chemical impacts on the organisms in the treated water. The basic form of the impact is the formation of cavitation, which can be defined as the rapid formation and collapse of microscopic gas bubbles in liquid as the molecules in the liquid absorb ultrasonic energy.
- US can affect viruses and bacteria effectively.
- Large systems are available that could be effective in treating ballast water and large volumes of water. These treatment systems, however, are mainly developed for industrial purposes and onboard solutions are scarce.

US Technology II/II

- Inactivation rates of 100% have been achieved in larger organisms and a 6.7 log reduction in bacteria and viruses.
- The capacity of the US system is also dependant on the power delivered. High intensity US devices require less exposure time for mortality to occur thus allowing higher flow rates to be treated.
- High power US supply systems can be used for ballasting and deballasting, while less effective systems may have their applicability range in ballast tank treatment.

Ozone technology I/II

- An essential feature is also the contact time required, thus the deballasting or ballasting modes for larger ballast water amounts might be too expensive in full-scale applications.
- An optimum ozone application may be the supply configuration, where one or several ballast water tanks are equipped with ozone injection equipment, and these tanks are used as contact chambers.
- The ballast water should then be treated by pumping the water into these contact tanks from each tank, in order to achieve a long enough contact time.

Ozone technology II/II

- Treatment during ballasting would ensure that all ballast water pumped into the ballast tanks would be exposed to ozone at the beginning of the voyage.
- If a long contact time is not required for the target organisms, disinfection would be ensured.
- In cases where the target organisms require longer contact times, treatment during ballasting would not be efficient enough and therefore treatment during voyage would be a solution for enabling longer contact times.

Cost evaluation

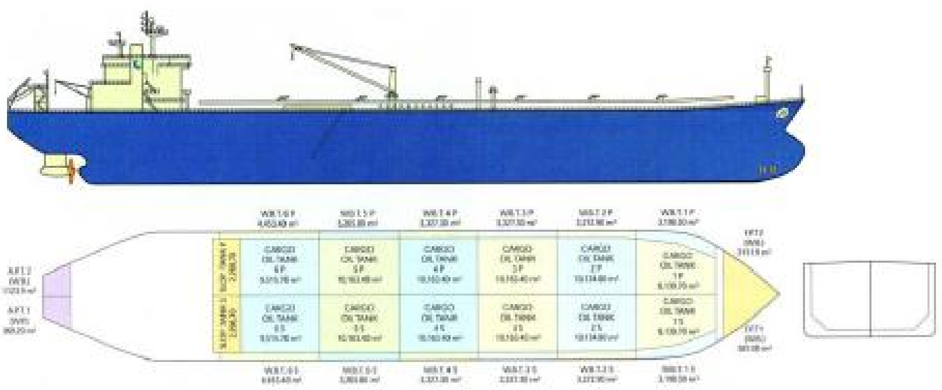
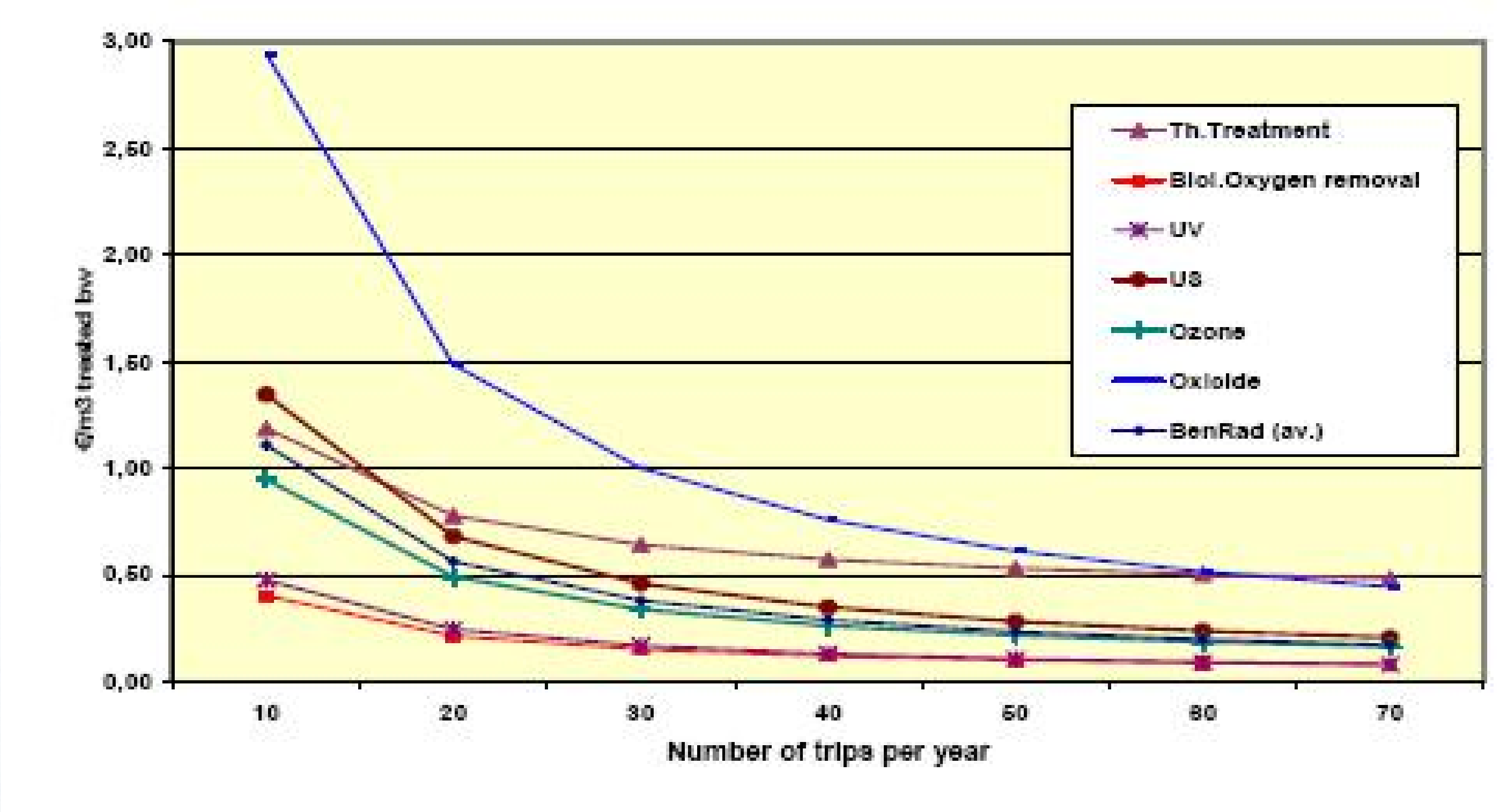


Figure 8. The layout of the ballast water and cargo oil tanks on Tempera (Neste Shipping, 2005).

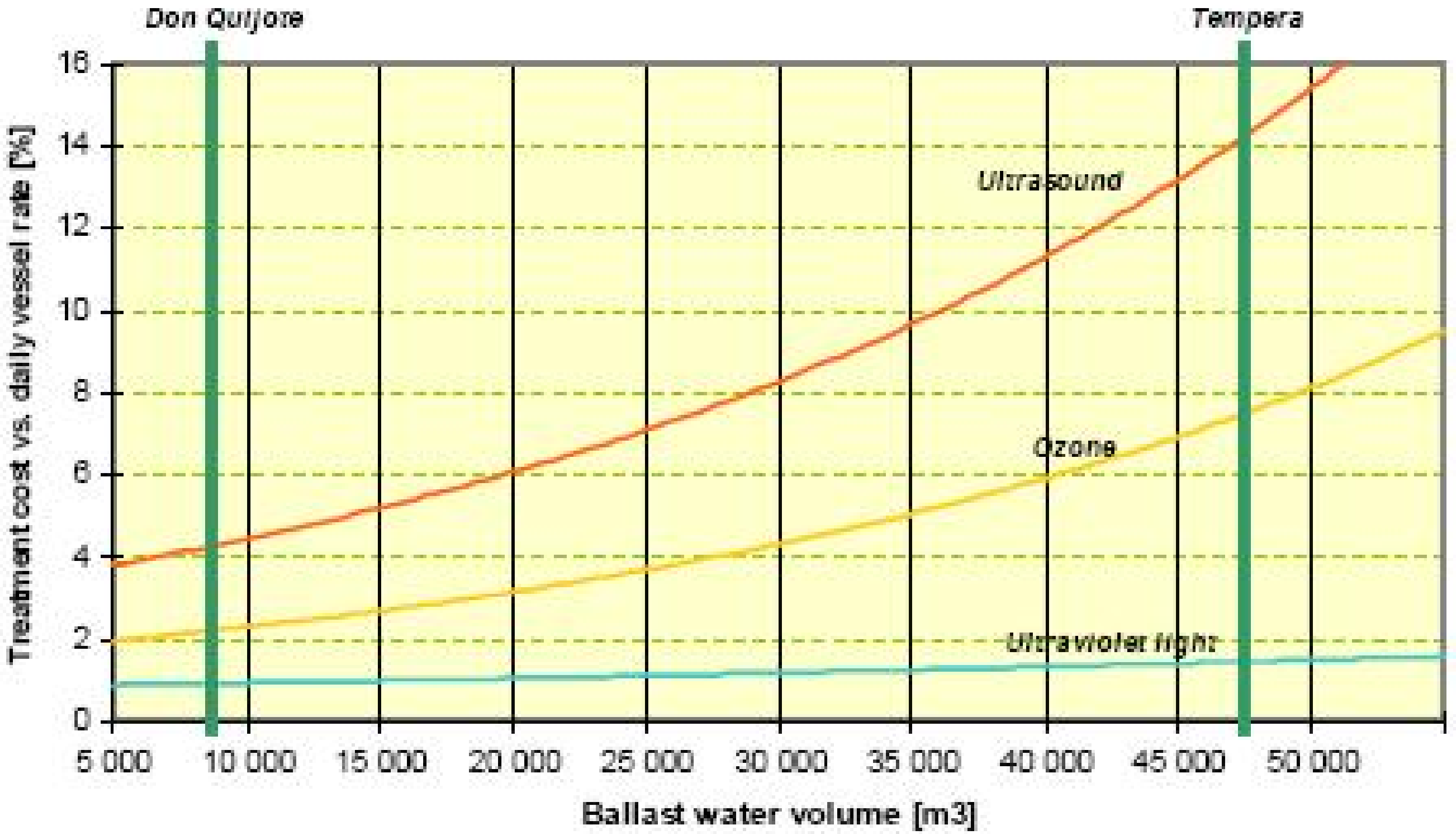
Figure 9. M/V Don Quijote, 14,800 dwt pure car and truck carrier (Wallenius Lines, 2005).

Cost per m3 of treated water

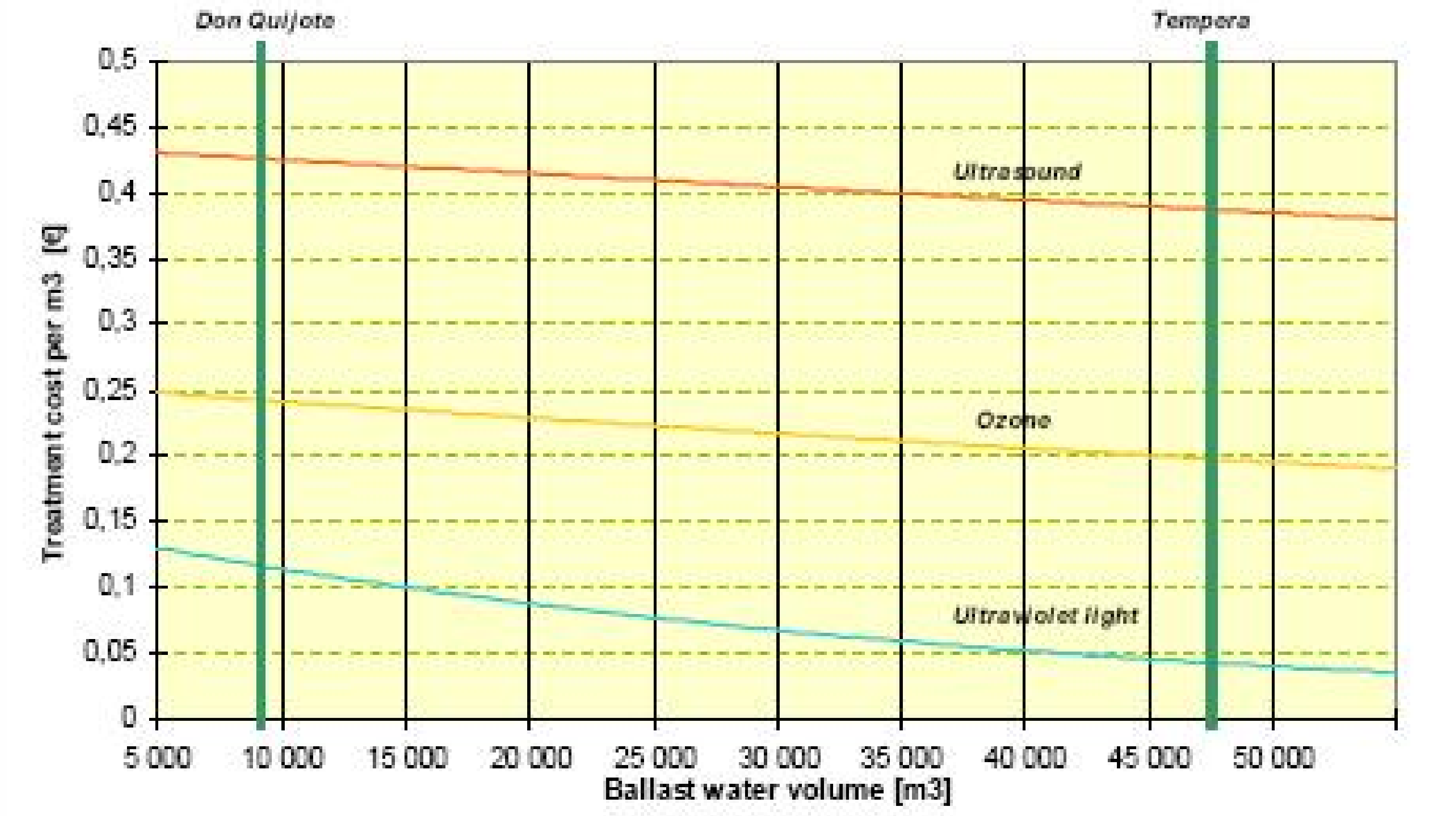
(Ellis & van der Woerd, 2004).



The estimated proportions of the treatment cost for the14,800 dwt PCTC (Don Quijote) and the 106,000 dwt oil tanker (Tempera).



The estimated cost per m3 for UV, US and ozone treatments for the 14,800 dwt PCTC (Don Quijote) and the 106,000 dwt oil tanker (Tempera).

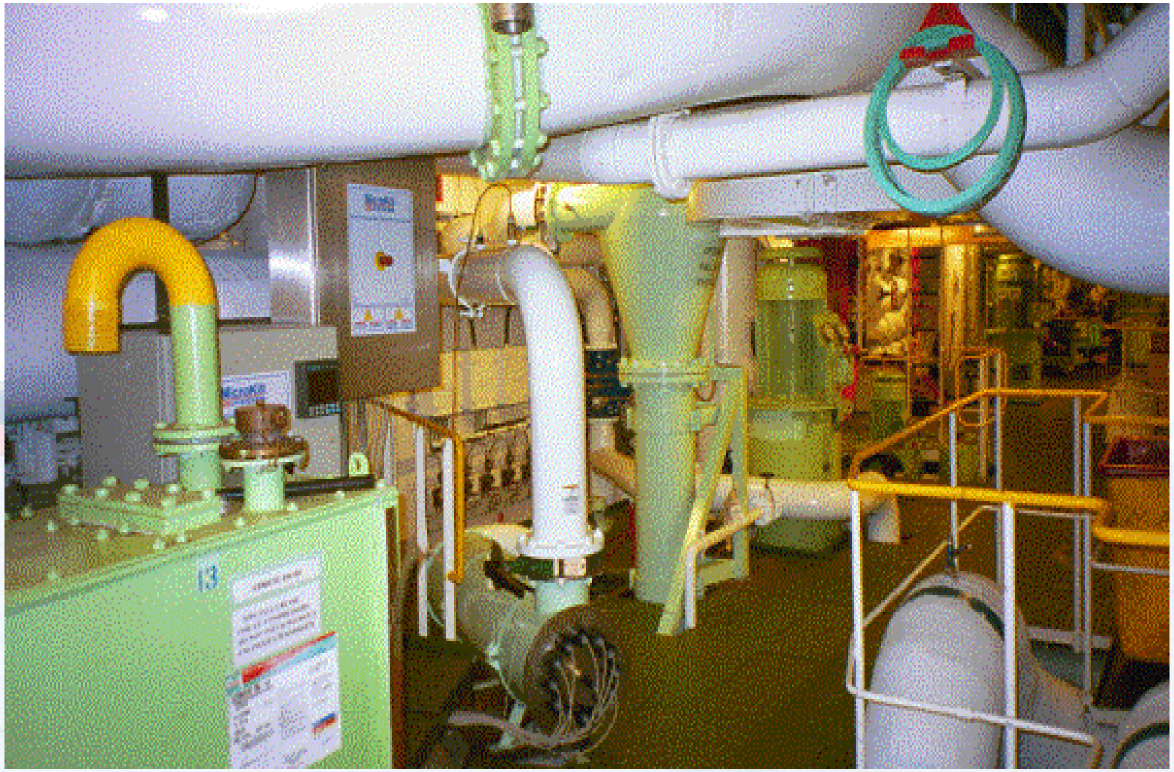


Ballast water quality and sediment consideration

Parameter/device	Filtering	Disk filter	Hydrocyclone
Safety	safe, installation after ballast pump	safe, installation after ballast pump	safe, installation after ballast pump
Biological effectiveness	95% removal up to 50 µm; 70–80% microzooplankton, phytoplankton	95% removal up to 50 µm; 70–80% microzooplankton, phytoplanton	50% removal; protect the primary (secondary device) restricted removal capacity
Environmental acceptability	usually needs a secondary treatment system; disposal should be carried out when ballasting	usually needs a secondary treatment system; disposal should be carried out when ballasting	usually needs a secondary treatment system; disposal should be carried out when ballasting
Status of technology	several applications tested, device capacities in the order of 2000 m^3/h	several applications tested, device capacities should be enlarged, with back-wash systems	several applications tested, some application in operative use, sizes in the order of few hundred tons/hour.
Cost	capital cost, 40,000–100,000$; larger devices more expensive	–	combined with UV, 120,000–140,000 $; larger devices 500,000 $

Full scale installations examples

Ozone generator onboard S/T Tonsina (photo: http://www.nutech-o3.com/)



OptiMar Ballast treatment system (cyclon + UV) aboard the “Regal Princess” (photo: http://www.optimarin.com/)

Conclusions

- The onshore trials with UV, US and ozone treatment options demonstrated that all of the technologies have potential for ballast water treatment.
- Equipment installations onboard a vessel is a complicated task because the ballast pumps, pipelines and valves are located in or near the pump room, which is one of the most crowned and densely packed areas on the vessel.
- The duration of the voyage is an important parameter when estimating the feasibility of various treatment options: the shorter the time for treatment, the higher dose of disinfectant or energy will be required and higher capital and operational costs will be evident.

IMO MEPC 53 - Conclusion

- Based on the data provided, the Review Group came to the conclusion that the varieties of systems being tested onboard have the potential to meet the criteria of safety, environmental acceptability and practicability

- Therefore, it is reasonable to expect that ballast water management technologies and type-approved systems will be available by October 2008

Cost estimations for various treatment options

Treatment option (no primary treatment)	**Costs [€ / m^3]** (Ellis et al, 2004)	**Costs [€ / m3]** (VTT, 2005)	**Costs [€ / m3]** (Glosten-Herbert, 2002)
Thermal treatment	0.53		
Biological Oxygen Removal (De-oxygenation)	0.10		
Ultraviolet light	0.10	0.045 - 0.11	0.06 / 0.10 (with cyclons)
Ultrasound	0.28	0.39 - 0.43	
Ozone	0.22	0.20 - 0.24	
Oxicide	0.61		
AOT	0.23		

- Case study ships:
  - Don Quijote PCTC; 56,893 gross tonnages, BW volume 8,076 m^3, BW pumps capacity 500 m^3/hr (Ellis et al, 2004)
  - Don Quijote and Tempera 106,000 dwt oil tanker, BW volume 46,900 m^3, BW pumps capacity 2,500 / 3,000 m^3/hr (VTT, 2005)

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Experiments with ultraviolet light, ultrasound and ozone technologies for onboard ballast water treatment

Further Information

- IMO - http://www.imo.org/
  - Convention
  - IMO Global Ballast Water Management Programme (GloBallast): http://globallast.imo.org/

- Manufacturers web-sites

- VTT Report "Experiments with ultraviolet light, ultrasound and ozone technologies for onboard ballast water treatment"
  - http://www.vtt.fi/inf/pdf/