Abstracts

2nd International
Ballast Water Treatment R&D Symposium

IMO London 21-23 July 2003

National Science Foundation USA

UNIVERSITY OF NEWCASTLE UPON TYNE
SCHOOL OF MARINE SCIENCE AND TECHNOLOGY

Maritime and Coastguard Agency

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Name of Paper	The ternary effect for ballast water treatment
Treatment options researched	*Disc Filtration, UV disinfection, Advanced Oxidation Processes*
Principal Researcher(s)	Arkal Filtration Systems, The Hebrew University of Jerusalem, Northeast Midwest Institute
Contact Details	Itay Kreisel, Chief Technologist Arkal Filtration Systems Bet Zera, Jordan Valley, 15135, Israel E-mail: itayk@arkal.com Fax: 972 4 6775461 Phone: 972 4 6775140
Host Institution(s)	
Location of Research	Israel, USA
Funding Level	
Funding Source(s)	Arkal Filtration Systems, Northeast Midwest Institute
Timeframe of the Project	
Aims and objectives of the project	To develop a commercial full scale Ballast Water Treatment Unit
Research Methods	Laboratory scale tests: • Reactive Oxygen Species Research, Prof. Sasson, Arkal Filtration Systems - to maximize hydroxyl radicals concentration in sea water. • Dose Response tests, NEMW Institute, Lake Superior Research Institute, Prof. Blatchley, Trojan Technology, Arkal Filtration Systems - to optimise UV dose within the "Ternary System" using Rotifers as indicators. Pilot scale tests: • First set of pilot tests, Arkal Filtration Systems, Dr. Galil - to check the physics and chemistry of the Ternary System (prototype one). Also-to examine inactivation of taxa. Flow rate-10 m3/hr. Source-Mediteranean Sea. • Second set of pilot tests, Arkal Filtration Systems, Dr. Galil, Prof. Sasson - to check the physics and chemistry of the Ternary System (prototype two). Also-to examine inactivation of taxa. Flow rate-10 m3/hr. Source - Mediteranean Sea. Engineering tests: To design and operate a full BWT unit onboard a ship. 5 replications taken for each experiment. Raw sea water taken at same time as samples for control.
Results	First prototype pilot plant led to the "Ternary Effect" which was followed by a pending patent. This patent deals mainly with an advanced filtration concept. Regarding taxa inactivation: Microplankton - 93% inactivation (above 80 micron), mainly-toraminiferans and crustaceans. Picoplankton - 100% inactivation, heterotrophic protist as indicator. Nanoplankton - 62% inactivation, mainly - diatoms and ebrida. R.O.S. Research led to a finding of a catalyst which was followed by a second pending patent. Dose response tests are underway. Second prototype pilot plant implementing the "Ternary Effect" is underway.

Notes

Name of Paper	Progress report on the 'Special Pipe System' as a potential mechanical treatment for ballast water
Treatment options	*Mechanical treatment system using a special pipe*
Principal Researcher(s)	Dr.Hiroshi Tokuda, Dr. Hiroharu Kato, Dr. Yasuwo Fukuyo, Capt. Takeaki Kikuchi, Mr. Seiji Kino, Mr. Katsumi Yoshida
Contact Details	Captain Takeaki Kikuchi : The Japan Association of Marine Safety, Toranomon 1-17-1, Minato-ku, Tokyo 105-0001, JAPAN Tel:+81-3-3805-3543 Fax:+81-3-3581-6136 Email:kikuti@oak.ocn.ne.jp
Host Institution(s)	Marine Pollution Prevention Research Department The Japan Association of Marine Safety
Location of Research	Laboratory of Marine Technology of Kyushu-Island.
Funding Level	US$370,000(2002), US$450,000(2003)
Funding Source(s)	The Nippon Foundation
Timeframe of the Project	**Phase 1: 1999-2000**: Basic research of the special pipe system with and without addition of ozone to the system **Phase 2: 2001-2002**: Fixed point testing of the improved special pipe systems at Imari Port **Phase 3: 2003** (in planning and to be carried out before March, 2004): On board testing of the improved special pipe systems
Aims and objectives of the project	The objective of this study is to develop a ballast water treatment system to terminate and eliminate harmful aquatic organisms contained in ballast water with special attention to criteria related to safety of ship and crew, practicability in terms of operational complexity and installation on board ships, cost effectiveness, and consequential environment impacts in addition to the effectiveness of treatment.
Research Methods	The prototype special pipe system was designed to use shear stress to terminate planktonic organisms. The potential was high, as reported at MEPC 44 in 2000, and verbally at the 1st International Ballast Water Treatment R&D Symposium (2001, London) and at the First International Conference on Ballast Water Management (2001, Singapore). This structure was, however, not suitable for practical use, because its pressure loss in passing water was high and needed higher pressure in a pipe with a larger diameter. The higher pressure could not cause higher damage to organisms in the pipe. Then the special pipe was re-designed with a unit generating shear stress and cavitations. Comparison of effectiveness between the former and the developed special pipe systems was made to ascertain the higher level of effect on marine organisms and the smaller pressure loss in the case of developed one.
Results	**Effectiveness of the prototype special pipe** One-passage treatment gave an effectiveness of about 55% of phytoplankton and about 65% of zooplankton killed and inactivated, and by injecting ozone they increased to about 99% and 89% respectively. **Effectiveness of the improved special pi pe** The improved special pipe system can kill and inactivate about 70% and 95 % of all phytoplankton and zooplankton respectively, in natural seawater in the case of one-passage treatment at the seawater flow rates 115 m^3/hr. This effectiveness was obtained using 60% of the energy of the prototype pipe. This effectiveness increased about 80% and 100 % respectively by two-times passage treatment, and furthermore they reached 85% and 100 % respectively at flow rates 150m^3/hr. **Size of system and installation cost** The main part of the system can be installed as a part of ballast water intake line or discharge line. The size is 1m long and 0.5m height in case of pipe having the inner diameter 100 mm. On board ship test will be practiced in the latter half of this year 2003. The installation cost of the system could be estimated as US$100,000 per unit, and the running cost could be US$0.01 per ton.

Notes

Name of Paper	Progress report on the AquaHabiStat (AHS) deoxygenation system
Treatment options researched	*Mechanical deoxygenation on intake*
Principal Researcher(s)	Wilson J. Browning, Jr. (Inventor and Coordinating Investigator), J. Parker Davis, Wilson J. Browning III Captain Claude Thompson, US Coast Guard (Ret.) Former Chief of the Engineering Faculty of the USCG Academy Dr. Roger Mann, PHD, Professor of Marine Biology and Deputy Director of the Virginia Institute of Marine Science
Contact Details	AquaHabiStat 223 East City Hall Ave. Suite 200 Norfolk, Virginia 23510 Tel: 757-233-7278; Fax: 757-625-7456 www.AquaHabiStat.com Email@aquahabistat.com
Host Institution(s)	Virginia Institute of Marine Science Old Dominion University Hampton Roads Sanitation District
Location of Research	South Eastern Virginia, United States
Funding Level	Approximately $4 million
Funding Source(s)	State government, Private Investors, NOAA
Timeframe of the Project	Initial prototype testing summer and fall 2000. Anticipated vessel and flow rate testing summer and fall 2003
Aims and objectives of the project	The main objective is to show that the AHS system is both effective at reducing nearly all larval aquatic invaders in the ballast water of ships and is capable of doing so at high flow rates. While the AHS prototype has demonstrated capability of functionality suitable for many commercial vessels, it would like to broaden the spectrum capabilities to coordinate with the cargo discharge rates of the normal operational procedures of larger vessels such as tankers. Current planning and funding is in process to show that the same prototype system will maintain efficacy at an anticipated flow rate of 300 tons per hour, onboard a vessel or barge. AHS anticipates executing onboard comparison tests that will allow it to gather direct data of the effects of vacuum deoxygenation as compared directly to ballast exchange procedures.
Research Methods	In the experiments taken in summer of 2000, micro-organisms including zooplankton (>75 and 80 µm) as well as biomass were monitored in treated and untreated water samples using 18 foot diameter 20,000 litre pools loosely covered with black plastic for better simulation of a dark ballast tank. Replication and Control methodology was established in multiple stages. First, The entire experiment consisted of three separate, sequential 10-day time - series tests, simulating the ballast voyages of three separate bulkcarriers returning to Hampton Roads in ballast from Europe, to load a new cargo of coal. Sampling was conducted about 1000 meters from the coal piers, which receive the highest concentration of ballast water discharge in the United States. The three replicate simulated voyages were organized as if they carried both treated and untreated ballast water. Also, each of the three separate individual sequential tests provided a control on any one single other of the individual tests in the event that a single test encountered unusual conditions in the ambient water being drawn from the Elizabeth River for testing. Averages of the three were used for reporting purposes.

	Additional replication and control issues were addressed by utilizing two separate laboratories from two separate disciplines [i.e. university, and municipal forensic sanitation laboratories]. Each of these maintained their own replicate and control procedures as outlined in “Pool Sampling”. Neither of these laboratories are affiliated with AHS except to having received remuneration for their efforts. AHS served only as the Engineering and Coordinating Investigator. The obvious high correlation of the various separate tests, different sampling techniques, and separate double-lab analyses created a high enough level of confidence in the results such that funds were not expended on formal statistical correlations and crosscorrelations.The water in the pools was monitored for water quality (dissolved oxygen, temperature, salinity, conductivity, and pH).
Results	The AHS system removed dissolved oxygen (DO) from ballast water to levels below 1 ppm with a vacuum equivalent of negative 14.2 psi and, after three days in the treated water, all larval stages that could become “nuisance species” and other organisms 75 microns and above were eliminated.

Notes

Name of Paper	Evaluations of deoxygenation as a ballast water treatment to prevent aquatic invasions and ship corrosion
Treatment options researched	*Deoxygenation through Venturi Oxygen Stripping*
Principal Researcher(s)	Mario N. Tamburri Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, USA Brenda J. Little, Naval Research Laboratory, Stennis Space Center, USA Gregory M. Ruiz, Smithsonian Environmental Research Center, USA Jason S. Lee, Naval Research Laboratory, Stennis Space Center, USA Peter D. McNulty, NEI Treatment Systems, Inc., USA
Contact Details	Dr. Mario N. Tamburri Chesapeake Biological Laboratory University of Maryland Center for Environmental Science P.O. Box 38 / One Williams Street Solomons, MD 20688 Phone: 410-326-7440, Fax: 410-326-7428, E-mail: tamburri@cbl.umces.edu
Host Institution(s)	Chesapeake Biological Laboratory
Location of Research	Solomons, Maryland; Key West, Florida; Stennis, Mississippi, USA
Funding Level	Approximately $500,000
Funding Source(s)	National Oceanic and Atmospheric Administration
Timeframe of the Project	January 2003 – September 2004
Aims and objectives of the project	Our current investigations are providing the critical information required to evaluate the efficacy and feasibility of deoxygenation as a ballast water treatment to prevent aquatic invasions and tank corrosion. Specifically, we are: (1) exploring the Venturi Oxygen Stripping™ system developed by NEI Treatment Systems, Inc. to optimize the deoxygenation process, (2) examining the impact of this oxygen stripping technique on the immediate and long-term survival of natural Chesapeake Bay planktonic organisms, and (3) quantifying corrosion rates and establishing the corrosion mechanism under deoxygenated conditions (with particular emphasis on microbiologically influenced corrosion and the production of hydrogen sulphide). These results will ultimately lead to a full-scale shipboard evaluation of deoxygenation as a cost-saving ballast water treatment.
Research Methods	
Results	

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Name of Paper	**Ballast water treatment by de-oxygenation with elevated CO_2 for a shipboard installation – a potentially affordable solution**
Treatment options researched	*Hypoxia combined with elevated carbon dioxide levels*
Principal Researcher(s)	Mo Husain and Horst Felbeck
Contact Details	Mo Husain, President MH Systems, Inc. 10951 Sorrento Valley Road, Suite 2F, San Diego, CA 92121 USA T: 858-452-1280 F: 858-452-6035 husainm@mhsystemscorp.com
Host Institution(s)	MH Systems, Inc. and Scripps Institution of Oceanography
Location of Research	San Diego, California
Funding Level	Not Available
Funding Source(s)	Internal R&D
Timeframe of the Project	2 Years
Aims and objectives of the project	The goals of the project were: a) Test the effect of "inert gas" on marine organisms as a possible treatment method for ballast water b) Establish a basic design for a full scale treatment system Estimate the costs of the treatment for the ship operator
Research Methods	Several different marine invertebrates, plankton and *Vibrio cholerae* were incubated in experiments to determine their survival. The parallel incubations were gassed with nitrogen (anaerobic) or "Trimix" (2% oxygen, 12% carbon dioxide, balance nitrogen). Aerobic controls, which were gassed with air, were done in parallel for each incubation. All incubations were done with several to many specimens of each species (depending on size and availability).
Results	All organisms tested died within a few hours after incubation in Trimix. The survival rate appears to be significantly shorter than an anaerobic incubation alone. All invertebrates showed no mortality in aerobic incubations. *Vibrio cholerae* was non viable (>99%) after an incubation period of 24h.

Notes

Name of Paper	Does heat offer a superior ballast water treatment option?
Treatment options researched	*This work involves the use of heat treatment using various engineering designs to kill or inactivate harmful organisms present in ballast water*
Principal Researcher(s)	Geoff Rigby[1], Gustaaf Hallegraeff[2] and Alan Taylor[3]
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Host Institution(s)	Reninna Pty Limited, University of Tasmania, Alan H Taylor & Associates
Location of Research	Hobart and Newcastle, Australia and on-board the *Iron Whyalla*
Funding Level	Estimated overall program costs approximately A$250,000
Funding Source(s)	BHP, AQIS, Shipping Industry, Reninna Pty Ltd, University of Tasmania, Alan H Taylor & Associates
Timeframe of the Project	1993 to present time
Aims and objectives of the project	The overall project objective has been to test the viability of heat treatment as a means of killing or inactivating harmful ballast water organisms and to develop practical and cost effective designs for implementation of the technology. The most recent work has sought to gain a better understanding of the biological effects of heat for the range of organisms and conditions likely to be encountered in ballast water and to extend the initial range of options and designs for future extension and implementation of this technology.
Research Methods	This work has involved a range of laboratory studies coupled with on-board full-scale ship trials on the *Iron Whyalla* as well as the investigation of engineering designs, cost effectiveness and practicality of a range of designs for various ships and voyages.
Results	New data and biological interpretations of the effects of heat on marine organisms have identified that a threshold treatment temperature of 40-45^{O}C is generally sufficient to kill or inactivate most organisms of concern in ballast water. Lower temperatures with longer treatment times are likely to be more effective than shorter times at higher temperatures. A number of full scale shipboard case studies for various heating regimes utilising waste heat from the ship's cooling systems, auxiliary steam condenser cooling water auxiliary boiler and other heat sources are presented for a variety of ships, voyages and operating conditions.

Notes

Name of Paper	Treatment of residual ballast water in the NOBOB ship using heat.
Treatment options researched	*Heat*
Principal Researcher(s)	[1]David T. Stocks, [2]Martin O'Reilly.
Contact Details	[1.] BMT/Fleet Technology Ltd., Kanata, ON. Canada. [2.] ESG Stantec Consulting Inc., Guelph, ON. Canada
Host Institution(s)	
Location of Research	Great lakes Region Canada
Funding Level	$150,000
Funding Source(s)	NOAA.
Timeframe of the Project	2003
Aims and objectives of the project	To establish thermo-toxicity of typical ballast-borne biota through laboratory toxicity testing. Heat treatment of ballast water to reduce aquatic invasive species has been proposed and tested in large ocean going ships where time in ballast and available energy is such that sufficient rise in temperature of the ballast water can be achieved. In the Great Lakes, ships do not have long periods of time in ballast nor sufficient energy to perform full ballast tank heating. By restricting the heat treatment to the residual ballast water, the time and energy requirements for treatment are significantly reduced to within the capacity of the typical NOBOB ship entering the Great Lakes. The study examines the heat requirements for the thermal treatment of residuals in a NOBOB ship, and determines if the energy demand for the treatment is within the capacity of a ship's normal generation and/or can be done economically using shore based equipment.
Research Methods	Ship board trials, heat dissipation modelling, thermo toxicity testing. A heat dissipation model is developed, using variational finite difference techniques, to quantify heat loss from the residual ballast water to the surrounding environment. An at ship experiment using portable heat (steam) generating equipment is conducted to calibrate the heat dissipation model and demonstrate the energy requirements needed to achieve the temperature profile deemed effective in the thermo-toxicity tests.
Results	TBD

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Name of Paper	The use of heat for ballast water disinfection – the AquaTherm method
Treatment options researched	*Physical Heat*
Principal Researcher(s)	Glenn Thornton, Robert Prentice
Contact Details	Hi Tech Marine Pty Ltd PO Box 215 Cooma NSW 2630 Australia Phone: +61 2 6452 6850 Fax: +61 2 6452 6520 Email: gthornton@htmarine.com.au
Host Institution(s)	None
Location of Research	Sydney, NSW
Funding Level	N/A
Funding Source(s)	Private
Timeframe of the Project	1995 – ongoing
Aims and objectives of the project	Disinfection of Ballast Water prior to loading or prior to discharge
Research Methods	Construction of several small systems that meet or exceed the thermal threshold of the target organisms. Results assessed by independent laboratories.
Results	All target organisms killed. Complete inactivation of: Reovirus; Enterovirus; and Norwalk virus. Reduced Adenovirus from 8850 to 22 units/L.

Notes

Name of Paper	Application study of ballast water treatment by electrolysing seawater
Treatment options researched	*The treatment method employed in this paper is the electrolysis of seawater.*
Principal Researcher(s)	Kun Dang, Peihai Yin, Peiting Sun
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Host Institution(s)	Dalian Maritime University
Location of Research	Marine engineering college, DMU
Funding Level	US$ 4,000+ R¥20,000
Funding Source(s)	GloBallast Programme and COSCO
Timeframe of the Project	2002.11-2004.4
Aims and objectives of the project	To develop a model of a ballast water treatment unit that is used to treat ballast water by means of electrolysing seawater. The capacity can meet the requirements of IMO conventions and the requirements of ship survey. The system can regulate the chlorine concentration produced according to the content of harmful organisms in the seawater and the temperature of the seawater. This then is used to kill all harmful organisms and pathogens with free residual chlorine kept in a minimum level. To make a blue print for the installation of the system on board.
Research Methods	Raw seawater and seawater with different concentrations of *Artemia salina* are simulated as ships' ballast water and treated by electrolysis
Results	The results of the experimental study are the following. • If the raw seawater is treated by electrolysis, it can kill 4 kinds of alga from 18 kinds with an initial chlorine concentration of 4.0ppm. The total mortality of phytoplankton can be up to72% and the mortality of bacteria is 99.99%. *Euciliata sp* in the seawater can be killed immediately. • If the seawater with an *Artemia salina* density increased from 2 individual/ml to 6 individual/ml is treated by electrolysing with an initial chlorine concentration of 4.0ppm, the mortality of *Artemia salin* is more than 95% after 48 hours of contact. • If the seawater with an *Artemia salina* density of not more than 2 individual/ml is treated by electrolysing with an initial chlorine concentration of 8.0ppm, the mortality of *Artemia salina* is more than 95% after 24 hours of contact. With an initial chlorine concentration of 15 ppm, 99.99% of *Artemia salina* is killed after 12 hours of contact. • If the residual chlorine in the treated seawater is less than 0.5ppm, the chlorine will have no effect on *Artemia salina*.

Notes

Name of Paper	Electro-sanitization of ballast water
Treatment options researched	*Electro-ionization*
Principal Researcher(s)	C.E.Leffler[1], Andrew Rogerson[2]
Contact Details	[1]Phone: +1 561 842 9900 Fax: +1 561 842 9922 Email: bud@mepi.net Marine Environmental Partners, Inc. (MEP) 3874 Fiscal Court, Suite 200 West Palm Beach, Florida 33404 USA Website: www.mepi.net [2] Nova Southeastern University
Host Institution(s)	Marine Environmental Partners, Inc.
Location of Research	Marine Environmental Partners, Inc. Nova Southeastern University
Funding Level	Private funding
Funding Source(s)	Marine Environmental Partners
Timeframe of the Project	Spring 2002 – May 2003
Aims and objectives of the project	Refine laboratory and shipboard electro-ionization systems for ballast water sanitization. Develop biological and chemical tests to evaluate performance and safety of treatment. Design a scalable system to treat ballast on diverse ship types.
Research Methods	Sanitization Efficacy - Bacteria and Protist Enumeration - Chlorine/Bromine (4500-ClF. DPD Ferrous Titrimetric Method) - Oxidative Reduction Potential (ORP) (2580 Oxidation-Reduction Potential) - Reduction Potential Analysis (Conducted by Nanospec Company) Effluent Safety - Acute and Chronic Toxicity (Conducted by Toxikon Corporation) - Chlorinated/Brominated organics (Mass Spectroscopy Method 8260) conducted by Spectrum Laboratories General - Dissolved oxygen (4500-0 G. Membrane Electrode Method) - pH (4500-H+) - Temperature (2550) - Conductivity/Salinity (2520 B. Electrical Conductivity Method) - Turbidity (2130 B, Nephelometric Method)
Results	MEP's electro-ionization system shows promise for use in sanitizing ballast water. The system as tested on Carnival's ELATION disinfected seawater (California coast, Pacific Ocean, and Florida coast, Atlantic Ocean) to at least a 95% kill of biota. The effluent safety also shows promise. No detectable trihalomethanes were present at de-ballast from the ELATION pilot trials. The concentrations of reactive halogens present at ballast discharge from the $1/20^{th}$ scale model testing to date were ecologically non-toxic producing no mysid shrimp mortality and no effect on mysid shrimp growth or fecundity. Chemical and biological research methods that were tested provided useful information for system development and for determining efficacy and safety.

Notes

Name of Paper	Superconducting magnetic separator for ballast-water treatment
Treatment options researched	*Mechanical (filtration and magnetic separation)*
Principal Researcher(s)	Norihide Saho
Contact Details	Mechanical Engineering Research Laboratory of Hitachi Ltd. 502, Kandatsu, Tsuchiura, Ibaraki 300-0013, Japan Tel;+81-29-832-4209, Fax;+81-29-832-8229, E-mail; saho@merl.hitachi.co.jp
Host Institution(s)	The Shipbuilding Research Association of Japan (offering) Corporation for Advanced Transfer & Technology (offering) Ship & Ocean Foundation
Location of Research	Japan
Funding Level	
Funding Source(s)	Corporation for Advanced Transfer & Technology (offering) Ship & Ocean Foundation
Timeframe of the Project	Phase1; 2003 Basic research of superconducting magnetic separation system for ballast water Phase2; 2004 Detail design of superconducting magnetic separation system on board Phase3; 2005 On board testing of the superconducting magnetic separation system
Aims and objectives of the project	The aim is developing of a ballast water treatment system that is suitable for rapidly purifying ballast water on board
Research Methods	A prototype water treatment system using a superconductor magnet to clean the ballast water discharged from ships was developed. The system is capable of treating 100 cubic meters of contaminated water a day through the following process sequence: mixing contaminated water with magnetic powder and a flocculant, stirring the mixture to make magnetic flocs, filtering the flocs, transferring them to a rotary magnetic shell, and dumping them in a sludge tank. The system was evaluated in experiments on two types of contaminated water samples, one containing kaolin particles and the other crude oil. Test species used were *Chattonella antiqua* and *Heterosigma akashio*.
Results	A continuous water-treatment system consisting of superconductor bulk magnets, which generate a high-intensity magnetic field, was developed and experimentally evaluated in tests on purifying several contaminated-water samples. The experiment showed that more than 90% of the particles in the contaminated water can be removed in about five minutes. This result indicates that this system is capable of purifying water continuously and at high speed within a limited space. It is concluded that the new water-treatment system is very effective for the treatment of ballast and oil-contaminated water, removing 96% of organisms.

Notes

Name of Paper	**Sodium hypochlorite as a ballast water biocide.**
Treatment options researched	*Biocides*
Principal Researcher(s)	[1]David T. Stocks, [2]Martin O'Reilly. [3]William McKracken
Contact Details	[1.] BMT/Fleet Technology Ltd., Kanata, ON. Canada. [2.] ESG Stantec Consulting Inc., Guelph, ON. Canada [3.] Consultant Michigan, USA
Host Institution(s)	
Location of Research	Great lakes Region Canada
Funding Level	$300,000
Funding Source(s)	State of Michigan, Great lakes Protection Fund, Transport Canada
Timeframe of the Project	2001-2004
Aims and objectives of the project	Evaluate the efficacy and impact of using Sodium Hypochlorite as a biocide for application to Great Lakes shipping. To address the concerns of the Michigan Environmental Science Board review of Phase 1 work and assist the State of Michigan in their legislation of ballast water treatment options.
Research Methods	A field demonstration on-board the MV *Federal Yukon*, Toxicology testing in the biological laboratory, Discharge impact assessment Corrosion testing in the material laboratory. Engineering development of ship systems and Economic evaluation
Results	Phase 1 results are not fully conclusive but demonstrate that Sodium Hypochlorite is an effective biocide, is economically feasible, has some detrimental effects on ship steel (corrosion). The assessment of impact on the receiving environment is still being developed.

Notes

Name of Paper	Effects of the chlorination treatment for ballast water
Treatment options researched	*Chemical biocide*
Principal Researcher(s)	S Zhang, X Chen, D Yang, W Gong, Q Wang, J Xiao, H Zhang, Q Wang,
Contact Details	Tel: 0086-411-4725440 Facsimile: 0086-411-4729777 Email: zhangshuohui@yahoo.com.cn Organization: Dalian Maritime University Postal address: Environmental science and engineering college, Dalian Maritime University, Lingshui Road 1,Dalian, 116026 P.R. China
Host Institution(s)	Dalian Maritime University, P.R. China
Location of Research	Dalian Maritime University, P.R. China
Funding Level	USD 40000
Funding Source(s)	GloBallast Programme
Timeframe of the Project	2002.9~2004
Aims and objectives of the project	This project deals with the effects of the chlorination treatment for ballast water.
Research Methods	• Bacteria test • Phytoplankton test • Natural seawater test • Amphipod test • Brine shrimp (*Artemia salina*) test • Breakdown test of available chlorine • Natural seawater, ballast water and sediment were treated with chlorination in the laboratory Three or four parallel samples are used in the test according to standard methods, such as: German ATS Benchmark or Chinese National Standard. Most of the tests are replicated. Some of the tests are replicated many times. Optimal conditions for test organisms are selected and standard poison is employed to ensure reliability of test organisms. Although there are a few differences among the test data of the replicating test, the test data is reliable. There is a control group in every test and once the mortality of control is over 10%, the data will be invalid.
Results	Our experiments select Sodium Hypochlorite as biocide. The results indicate that chlorination treatment is effective in killing organisms and bacteria in seawater. They also show that available chlorine with concentration of 20 mg/L is able to kill almost all the bacteria in the seawater. However, the concentrations of available chlorine for phytoplankton, zooplankton and benthic invertebrate's treatment vary depending on the species and the density of them, ranging from 5 mg/L to 100mg/L.

Notes

Name of Paper	Use of chlorine for ballast water treatment
Treatment options researched	*Chlorine*
Principal Researcher(s)	Julieta Salles Vianna da Silva Flavio da Costa Fernandes
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Host Institution(s)	IEAPM – Admiral Paulo Moreira Marine Research Institute
Location of Research	Bulker Frotargentina
Funding Level	
Funding Source(s)	Petrobras – Brazilian Petroleum S/A
Timeframe of the Project	March 1999 to September 2001
Aims and objectives of the project	The objective of this study was to assess the chlorine efficacy, to determine its minimum concentration eliminate organisms in ballast water and to observe the formation of trihalomethane on board. This study also is concerned about the evaluation of survival of microalgae and trihalomethane formation in laboratory in different concentrations of chlorine and cells.
Research Methods	The experiment was done in 8 wing tanks: 4 tanks used as control and 4 tanks treated with chlorine at 1, 3, 5 and 10 ppm. Every day, during six to eight days, samples were taken from every tank to analyze salinity, pH, temperature, dissolved oxygen, nitrite, nitrate, ammonium, phosphate, chlorine, trihalomethane, zooplankton and phytoplankton. Experiments in laboratory were made to assess the THM formation using *Tetraselmis chui* in different concentrations.
Results	The maximum mortality of total zoo- and phytoplankton was 76.4% and we did not find significant differences (<0.05) among treatments. Concentrations above 3 ppm are not recommended due to formation of high values of THM (>100µg/L). The lowest chlorine concentration tested (1ppm) presented the lowest THM concentration. It is suggested the use of low concentration of chlorine in continuous flux, to improve the chlorine efficiency.

Notes

Name of Paper	SeaKleen®, a potential product for controlling aquatic pests in ships' ballast water.
Treatment options researched	*Chemical (Biocide)*
Principal Researcher(s)	Stephen J. Cutler*, Horace G. Cutler, Jan Glinski, David Wright, Rodger Dawson and Denis Lauren
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Host Institution(s)	*Garnett Inc., Watkinsville, GA 30677 USA [2]Planta Analytica, New Fairfield, CT 06812 USA [3]University of Maryland, Center for Environmental Science Chesapeake Biological Laboratory, Solomons, MD 20688 USA [4]HortResearch , Ruakura Research Centre, Hamilton, New Zealand
Location of Research	Same as Host Institution
Funding Level	$500,000
Funding Source(s)	Private Company
Timeframe of the Project	July 2001-June 2003
Aims and objectives of the project	This project includes the evaluation of SeaKleen® against a variety of aquatic nuisance species residing in ballast tanks of ships. This project fills the gap on tests that have been performed since the 1st R&D Symposium in 2001. Furthermore, this study includes the degradation of the active principle in fresh and salt water studies using High Performance Liquid Chromatography (HPLC).
Research Methods	While investigating the use of various natural products as molluskocidal agents, it was observed that several agents belonging to the chemical class of naphthoquinones were found to be highly effective. Further investigation in the structure-activity-relationship led to the biologically active agent menadione, which is being developed under the trademark SeaKleen®. This product has been shown to possess significant efficacy against a wide variety of estuarine and fresh water organisms including *Cyprinodon variegatus*, *Eurytemora affinis*, *Isochrysis* sp., *Neochloris* sp., and *Glenodinium foliacium* cysts. In addition, current studies have shown SeaKleen® is very effective against free swimming *Glenodinium foliacium*, *Cyclopoidea* sp (Cyclops). In order to gain a better understating of its effects, studies were designed to evaluate SeaKleen® against the edible oyster, *Mytilus galloprovincialis* . Based on the broad spectrum activity of SeaKleen® against marine organisms and its high potential as a viable commercial product, it was of interest to determine the degradation of the active component, menadione, when subjected to normal applications. Using an HPLC assay, SeaKleen® was subjected to sterilized and unsterilized sea and fresh water over a period of 72 hours, and samples taken at 24 hour intervals, to determine longevity and breakdown.
Results	Results, to date, indicate that SeaKleen® may be an environmentally friendly and cost effective ballast water treatment to control invasive species.

Notes

Name of Paper	Peraclean® Ocean – a potential treatment option for ballast water
Treatment options researched	*Chemical treatment*
Principal Researcher(s)	Rainer Fuchs
Contact Details	Degussa AG Dr. Rainer Fuchs Rodenbacher Chaussee 4 D-63457 Hanau-Wolfgang Germany Tel: +49 6181-59-3892 Fax: +49 6181-59-3311 Email: rainer-g.fuchs@degussa.com Web: www.degussa.com
Host Institution(s)	---
Location of Research	Degussa AG, Germany
Funding Level	50% BMBF, 50% Degussa AG
Funding Source(s)	1) German Federal Ministry of Education and Research (BMBF), Germany 2) Degussa AG, Germany.
Timeframe of the Project	1998-2003
Aims and objectives of the project	The project was set up to explore possibilities for peroxygen chemicals to treat ballast water in an environmentally friendly way. Laboratory trials and field trials, e.g. on a ship, were planned.
Research Methods	Treatment of different waters that contained different species was done. Killing rates after different exposure times with different formulations and different species were observed.
Results	Peraclean® Ocean, a liquid oxidizer formulation showed the best results. Treatment of different waters that contained different species was done. For a first evaluation of the performance of Peraclean® Ocean, the *Artemia* Testing Standard (ATS-benchmark; contact: m.voigt@drvoigt-consulting.de) was applied at lab-scale. This benchmark test uses the brine shrimp, *Artemia salina*, as indicator organism. The ATS involves 4 different development stages of the brine shrimp: adults, larvae, nauplius-stages, pre-incubated eggs and cysts. The ATS-data showed that the addition of Peraclean® Ocean at levels of above 350 ppm resulted in 100% mortality of all *Artemia* live stages. Further experiments were carried out with a number of other indicator organisms. Dosing rates of 50 – 350 ppm Peraclean® Ocean and exposure times of 2-72 hours proved to be 100% effective (no survivals) for many different species. Results of these tests are presented in the paper. Peraclean® Ocean can be used alone or in combination with a separation of solids technology.

Notes

Name of Paper	Acrolein as a potential treatment alternative for control of microorganisms in ballast tanks: five day sea trial
Treatment options researched	*Chemical Treatment: Acrolein Technology (2-propenal)*
Principal Researcher(s)	Joseph E. Penkala, Ph.D., Melissa Law, and Jennifer Cowan, M.S.
Contact Details	Joseph Penkala Phone: 281.276.5674 Fax: 281.276.5492 Email: Joseph.Penkala@BakerPetrolite.com Baker Petrolite Corporation 12645 West Airport Blvd. Sugar Land, Texas 77478
Host Institution(s)	Baker Petrolite Corporation
Location of Research	Baker Petrolite Corporation: Sugar Land TX Technology Laboratories Gulf of Mexico: Guanta, VZ to Panama City, FL Houston Ship Channel
Funding Level	Corporate Allocation from Baker Petrolite Corporation
Funding Source(s)	Baker Petrolite Corporation
Timeframe of the Project	January 2002 to December 2002 Voyage: November 4, 2002-November 10, 2002
Aims and objectives of the project	Investigate the efficacy of acrolein in the control of microorganisms in ballast tanks aboard an 8000 MT DWT cargo ship on a 5 day voyage in the Gulf of Mexico.
Research Methods	Monitored growth of aerobic and sulphate reducing bacteria and levels of chemical residual daily from uptake to discharge. Utilized serial dilution culture techniques for enumeration of viable bacteria. Utilized differential pulse poloragraphy to monitor acrolein residuals. Sampling was conducted via port in ballast line during uptake and discharge and via ballast tank sounding tubes during voyage. Chemical application was into ballast line at the suction side of the ballast pump. The sample port and chemical port were on parallel lines to avoid mixing. A sea trial was conducted on board an 8000 MT DWT container vessel during a 5 day voyage from Venezuela to Florida. Dedicated ballast tanks were treated with 1, 3, 9, or 15 ppm of acrolein during ballast intake in Venezuela. Monitoring of viable bacteria and acrolein residuals was conducted prior to treating, daily during the voyage, and during discharge. Residuals of 1, 3, 9, and 15 ppmof acrolein were tested in this study.
Results	Acrolein is a broad spectrum biocide with proven efficacy against bacteria, algae, and other microorganisms. Extensive toxicity testing has demonstrated its effectiveness against macroorganisms as well, including mollusks, crustaceans, fish, and aquatic plants. Recent laboratory studies demonstrated that 1-3 ppm of acrolein can effectively control various marine microorganisms. When applied at treatment concentrations of 9 ppm, acrolein maintained 99.99 % efficacy for 2 days. At 15 ppm, acrolein was shown to be 99.9999 % effective for 3 days as compared to untreated ballast tanks. En route monitoring confirmed that regrowth of microorganisms was minimized when the acrolein residual was maintained at $\geq$2 ppm. At the time of discharge, the acrolein residuals were zero ppm, a consequence of its reaction with water, thus allowing its safe discharge overboard. These findings advocate the use of acrolein as an effective treatment strategy which can be managed safely, can be safely discharge into the marine environment, and is economical in the control of organisms in ballast water.

Notes

Name of Paper	Solution to ballast water pollution: ship shape and ports escape?
Treatment options researched	*On-shore treatment, applicability & use of on board treatment techniques and BWE*
Principal Researcher(s)	E. Donkers, R. van Gelder (Port of Rotterdam), J. Pluim, M. Kooi, Wittenveen+Bos Consultants
Contact Details	Edo Donkers Policy advisor Word Port Center Wilhelminakade 909 Port number 1247 Postbus 6622 3002 AP Rotterdam The Netherlands
Host Institution(s)	Port of Rotterdam
Location of Research	
Funding Level	No additional funds used
Funding Source(s)	
Timeframe of the Project	Estimated end time on board survey end of 2003-07-14
Aims and objectives of the project	Provide further insight into common practices ballast water management on board and about origins + destination of ballast water for the port of Rotterdam as a part of risk analysis. Short desk-top study on feasibility of on-shore treatment.
Research Methods	Desk and literature research (for on-shore treatment and risk analysis), on-board survey field research (common practices on board and origins/destination of ballast water).
Results	Cost estimates for treatment plant 1.5 €, excluding costs for on-shore infrastructure, port space use, reception infrastructure (barges etc.). Realisation of full reception facility must be considered very critically because of experiences in the past. First results of on-board survey indicate that ballast water exchange methods are widely used before port entry at Rotterdam.

Notes

Name of Paper	**Latest results from testing seven different technologies under the EU MARTOB project: Where do we stand now?**
Treatment options researched	*Thermal, UV, US, Ozone, Oxicide, De-Oxygenation and Advance Oxidation*
Principal Researcher(s)	Dr Ehsan Mesbahi (Project Manager) Prof. Atilla Incecik (Project Coordinator) Miss Ana Paula Esteves (Project Administrator)
Contact Details	School of Marine Science and Technology, Armstrong Building University of Newcastle, Newcastle upon Tyne, NE1 7RU, United Kingdom Tel: +44 -191 222 6723 (Ehsan.mesbahi@ncl.ac.uk) : +44 -191 222 6724 (Atilla.Incecik@ncl.ac.uk) Fax: +44-191 222 5491
Host Institution(s)	University of Newcastle upon Tyne, UK.
Location of Research	UK: UNEW, ABC, FRS, INTERTANKO, SOU, TQ, ICS Finland: AAU, VTT Netherlands: TNO, TME, BERSON, HW Norway: SINTEF, MARINTEK, Shell MP, WW, FUELTECH, NSA France: IFREMER, BV Sweden: ALFA LAVAL, SSPA Greece: EPE Denmark: MAN B&W.
Funding Level	Approximately €3.8 million.
Funding Source(s)	Partially funded by European Commission under the 5th Framework Programme for research, technological development and demonstration activities, GROWTH, (Directorate-General for Energy and Transport).
Timeframe of the Project	MARTOB started in April 2001and will run for three years.
Aims and objectives of the project	The objectives of MARTOB are: • To investigate methodologies for preventing the introduction of non indigenous species through ships' ballast water; • To develop design tools and treatment equipment to be used in the further development of ballast water treatment techniques; • To assess the direct and indirect environmental aspects of current and newly developed methods; • To develop cost-effective (capital and running), safe, environmentally friendly onboard treatment methods; • To produce guidelines for crew training and criteria for selecting appropriate ballast water management methods for different types of ship; • To assess the financial, technical and operational effects of a sulphur cap on marine bunker fuel in European waters, and propose a verification scheme ensuring compliance with a sulphur cap from all players in the market; To help to facilitate the introduction of an important sulphur emission abatement measure without unintentional distortion of competition in the shipping market.
Research Methods	Theoretical, laboratory tests and onboard sea trials.
Results	With the completion of MARTOB, it is envisaged that the results of this project would be able to provide an insight on global ballast water legislative measures and recommendations on probable future ballast water treatment solutions through research and shipboard trials. MARTOB will result in detailed recommendations for ballast water management solutions to IMO, ICES, IOC and other maritime organisations, marine environmental agencies and regulatory bodies.

Notes

Name of Paper	Shipboard trials of ballast water treatment systems in the United States
Treatment options researched	Mechanical: Separation and Filtration Chemical: Biocides
Principal Researcher(s)	Drs. David A. Wright and Rodger Dawson, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science.
Contact Details	Dr. David Wright, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, 1 Williams Street, P.O. Box 38, Solomons, MD 20688 USA Phone: 410-326-7240, Fax: 410-326-7210 E-Mail: wright@cbl.umces.edu Thomas P. Mackey, Hyde marine, Inc., 28045 Ranney Parkway, Cleveland, OH 44145 USA Phone: 440-871-8000 ext. 112, fax: 440-871-8104 E-mail: tmackey@hydemarine.com
Host Institution(s)	University of Maryland Center for Environmental Science
Location of Research	Baltimore, Maryland USA
Funding Level	$1,200,000
Funding Source(s)	National Oceanic Atmospheric Administration, Maryland Port Administration, U.S. Maritime Administration
Timeframe of the Project	2001-2005
Aims and objectives of the project	A variety of ballast water treatment technologies are scheduled to be tested at full-scale aboard ships of the U.S. reserve fleet. Two biocides and an ultraviolet light irradiation unit have been tested in 2001, and combination technologies including a centrifugal separator, a depth filter plus secondary treatments (biocides and UV) will be tested in 2003-2005.
Research Methods	Treated and untreated water samples from shipboard mesocosms and ballast tanks are examined for zooplankton (microscopic live/dead examination aboard the ship), phytoplankton growth potential (following a grow-out period under fluorescent light), acridine orange fluorescent bacterial counts and cultural bacteria (also following grow-out periods). In all cases treated samples are compared with untreated samples to determine the efficacy of each treatment. Water samples are also examined to determine particulate profile and water quality parameters.
Results	100 ppm Peraclean Ocean®, an inorganic oxidant and 2ppm Seakleen® (an organic, natural product cellular oxidant) were both effective in controlling zooplankton and phytoplankton in ballast water. UV irradiation, using a 32kW system was able to inhibit phytoplankton growth and resulted in zooplankton mortalities of >95% at ballast water flow rates of ca. 1500gpm.

Notes

Name of Paper	Development and design of process modules for ballast water treatment onboard
Treatment options researched	*Different treatment options to evaluate and combine most efficient process modules for the treatment onboard*
Principal Researcher(s)	Mrs. Dr.-Ing. Anja Kornmueller
Contact Details	Berkefeld Water Technology, Berkefeld-Filter Anlagenbau GmbH Lueckenweg 5, D-29227 Celle, Germany Phone: + 49 5141 803-273, Fax: + 49 5141 803-201 E-mail: a.kornmueller@berkefeld.de Internet: www.berkefeld.com
Host Institution(s)	Berkefeld Water Technology, Celle RWO Marine Water Technology, Bremen
Location of Research	Celle and Bremen, Germany
Funding Level	Approx. EUR 1 000,000.
Funding Source(s)	Federal Ministry for Research and Technology (Germany) and self-share by Berkefeld
Timeframe of the Project	Oct. 2002 – end of 2004
Aims and objectives of the project	• To evaluate the basics concerning the biological / aquatic and chemical / physical water characteristics, risk assessment and regulatory framework with a special focus on the identification and comparison of different treatment options available in the market and research, the basic conditions by vessels and their requirements on ballast water treatment systems • To develop efficient and cost-effective modular process combinations for ballast water treatment onboard
Research Methods	• Basic evaluation by desk based review (literature and internet inquiry; contact with organisations, authorities, research institutes and companies), practical examinations (like ballast water sampling) and assignment of different research institutes and companies to attribute their special expertise • Analyses: comprehensive survey by combining all relevant biological, chemical, physical and process parameters for ballast water treatment and setting of priorities; development of system specifications and definition of target and quality criteria for ballast water treatment, single processes and their combinations • Practical experiments on suitable treatment processes for sediment / particle removal and desinfection • Modular design of process combinations for ballast water treatment onboard
Results	• A theoretical review of studied treatment processes revealed that an overall treatment solution is not found yet due to variations in the water quality, the technical demands and the different requirements by vessel (such as operation, construction, area, purpose etc.) • A pilot plant for sediment / particle removal is running since end of June 2003 and will be upgraded stepwise to investigate different ballast water treatment options. Results are ongoing.

Notes

Name of Paper	Hydrodynamic cavitation and filtration treatment of ballast water
Treatment options researched	*Hybrid system including mechanical filtration in combination with hydrodynamic cavitation*
Principal Researcher(s)	Mr Anatoliy Mikhailovich Andryushchenko
Contact Details	Andryuschenko Anatoliy Director, CJSC „Engineering Center TRANSZVUK" 65014 Odessa, 6, Nahimova lane Tel: +38 0482 22 09 31 Fax: +38 0482 22 04 01 ?-mail: transsound@paco.net
Host Institution(s)	
Location of Research	
Funding Level	
Funding Source(s)	GloBallast Programme
Timeframe of the Project	February 2003 - December 2003
Aims and objectives of the project	• Search of the technological solution for ships' ballast water treatment according to criteria of Marine Environment Protection Committee, 48th session, document ???? 48/WP.15, 10 October, 2002. Regulations E-1 … E-4. • Developing of pilot ships installation. • Tests of hydraulic cavitation method efficiency for decontaminating of ballast waters in a combination with filtering. • Study of seawater hydraulic cavitation decontaminating in relation to macro and microorganisms, including bacteria etc. in a combination with filtering. • Analyze of the received results to demands of Regulations E-1 … E-4 of the international convention. • Estimation of the specific power costs.
Research Methods	The hydrodynamic cavitation decontaminating of fluids is based on local complex high-intense ultrasonic effect on a flow at high-speed phase changes, in aggregate with instantaneous (exemplary time of effect - 10-4…10-6 s) pressure changes. Thus the potent expensive electronic generators of ultrasound electrical transmitters are not applied, the thermal energy is not spent. In zone of sharp differential pressure at movement of fluids there is an instantaneous gas-making and, under certain conditions, generation of an ultrasound of high intensity in result of hydrodynamic effects. Generated in narrow zone of a flow the ultrasound effects breaking down a macro and micro-organisms structure. Besides, at a secondary pressure changes (from vacuum to overpressure), there is a so-called pressure jump caused by transition of medium velocity from ultrasonic to subsonic. In coverage of pressure jump happens collapse of steam-gaseous bladders, that is accompanied by potent mechanical effect on a fluid. The efficiency of a bactericide effect of ultrasonic oscillations depends on the form of micro-organisms, strength of chemical composition of cellular wall, availability of a sheath, age of culture, ultrasound intensity, frequency of ultrasonic oscillations and duration. It is known, that irradiation of water by ultrasound at specific output more than 3 W/ cm2 at frequencies 500 … 1000 kHz, happens complete breaking down of micro-organisms in water column by depth of 100 mms. The operation of ultrasound with a wave-length, commensurable dimensioned sounded organisms is most pernicious.

Pilot installation configuration:

1. Accumulator of incoming water.
2. Bowl of a reagent.
3. Vortical pump.
4. Module of a mechanical filtration.
5. Module of a saturation.
6. Bowl of exposure.
7. High-pressure pump.
8. Module of a hydrodynamic cavitation.
9. Module of a degassing.
10. Bowl of the treated water.

Results

- Estimation of applicability of hydraulic cavitation decontaminating for treating ship ballast waters according to demands of Regulations E-1 … E-4.
- Depends of water decontaminating degree (different macro and micro-organisms) on parameters of hydrodynamic processing, modes of seawater filtering and filter materials.
- Specific power costs.
- Technical advisories on designing full scale installation.

Notes

Name of Paper	A new modular concept for the treatment of ships' ballast water
Treatment options researched	*Physical separation: gravity separation and filtration* *Chemical disinfection: non-toxic, chlorine free oxidising agent (Peraclean® Ocean)*
Principal Researcher(s)	Hauke Röpell, Lothar Reinecke, Dr. Matthias Voigt
Contact Details	Hamann Wassertechnik GmbH Brookdamm 6, D-21217 Seevetal, Germany HaukeRopell@HamannWassertechnik.de Dr. Voigt Consulting Kampstraße 7, D-24601 Stolpe, Germany M.Voigt@drvoigt-consulting.de
Host Institution(s)	Hamann Wassertechnik GmbH
Location of Research	Lower Elbe River, Baltic Sea and Port of Hamburg
Funding Level	€ 260,000
Funding Source(s)	AIF (Federal Ministry of Research) Hamann Wassertechnik GmbH Dr. Voigt Consulting
Timeframe of the Project	2000-2003
Aims and objectives of the project	Testing of various physical separation options in combination with chemical disinfection of ballast water. Design of a full scale treatment plant for land based tests and evaluations. Identifying suitable combinations of above methods for various types of ships (e.g. ballast water management scenarios). Development of online monitoring systems for ballast water treatment.
Research Methods	On shore tests done at a flow rate of 135 to 210 m^3/h. Testing of different cyclones (gravity separation) and self cleaning filters at 100 and 50 µm as well as dosing of 50 to 200 ppm Peraclean® Ocean. Test carried out with in situ plankton population as well as selected indicator organisms (different life stages of artemia, ATS).
Results	The combination of gravity separation and filtration (50 µm) with a dosage of 150 ppm Peraclean® Ocean resulted in > 98% removal/mortality of all test organisms. Further full-scale test will be carried out on land and onboard a ship.

Notes

Name of Paper	A portable pilot plant to test the treatment of ships' ballast water
Treatment options researched	*Filtration, Ultraviolet, Ultrasonic shear*
Principal Researcher(s)	S Hillman, P Schneider, F Hoedt
Contact Details	Telephone: 61 7 4781 4779 Facsimile: 61 7 4775 1184 Email: steve.hillman@jcu.edu.au
Host Institution(s)	Organisation: CRC Reef Research Centre at the School of Engineering, James Cook University
Location of Research	Postal Address: Douglas Campus Townsville Queensland Australia 4811
Funding Level	A$670,000 (approx)
Funding Source(s)	Environment Australia, Ports Corporation of Queensland, Townsville, Mackay and Gladstone Port Authorities, Amiad Australia, CRC Reef Research Centre, Great Barrier Reef Research Foundation, Pasminco.
Timeframe of the Project	2002 - 2004
Aims and objectives of the project	The objective of project is to build a pilot treatment plant based on existing technologies and off the shelf equipment. Based on existing research results and applications developed by others, the pilot plant uses various technologies, as well as chemicals on a 'plug and play' basis. The medium to longer term aim is to develop a system that will be scaled up and used aboard ships.
Research Methods	Seawater can be stored in two 27,000-litre tanks. The water can then be drained to a 10,000-litre tank where it can be inoculated with the organism of choice. This tank is mixed using and aeration system to enhance homogeneity. This tank is connected to the main pump which delivers the water to any, or all, of the Amiad filter, the sonic disintegrator and the ultra-violet unit. Sampling points are available pre and post the pump and each treatment method. This filter can be used with a number of different sized screens and the project has available to it 20, 50 and 80 micron screens. To date only the 80-micron screen has been used. The sonic disintegrator is driven by a variable frequency drive that allows the speed of the machine to be varied to optimise effects. The ultra-violet unit operates at 254 nanometres. All components are designed to be able to be operated at greater than the design capacity of 3 litres per second. We have innoculated a 10,000 litre tank of seawater with varying numbers of *Artemia* (50 to 80 per litre). We have sampled at a number of points after the culture leaves the tank. These are pre and post the pump, filter and sonic disintegrator. We have done this with no treatment except the pump as well as with the filter engaged or the disintegrator in operation.
Results	Under development

Notes

Name of Paper	Ballast water treatments R&D in the Netherlands
Treatment options researched	*Filtration, Hydrocyclone, UV*
Principal Researcher(s)	Dr. Jan P. Boon, Dr. C.C. ten Hallers-Tjabbes, Ing. J.R. van Niekerk, J.L. Brouwer MSc
Contact Details	NIOZ: Dr. Jan P. Boon Man in the Marine Environment P.O. Box 59 1790 AB Den Burg Texel The Netherlands (31)(0)222 – 369466 E-mail: boon@nioz.nl
Host Institution(s)	Royal Netherlands Institute for Sea Research (NIOZ)
Location of Research	NIOZ, Texel
Funding Level	75%
Funding Source(s)	Netherlands Government
Timeframe of the Project	203 – 2006
Aims and objectives of the project	To investigate a combination of techniques: filtration & UV / Hydrocyclone & UV
Research Methods	3 phases: - A dockside test - Followed by a semi-full scale test at sea on the research ship The Pelagia - Followed by a full scale test on board of 2 large vessels
Results	No results so far. The testing period starts in the end of 2003

Notes

Name of Paper	Corrosion effects of ballast water treatment methods
Treatment options researched	*Treatment options likely to cause changes in the water affecting its corrosivity.*
Principal Researcher(s)	Egil Dragsund (DNV), Bjørn Olav Johannessen (DNV), Aage Bjørn Andersen (DNV), John Olav Nøkleby
Contact Details	Det Norske Veritas Egil.dragsund@dnv.com
Host Institution(s)	Det Norske Veritas, Veritasveien 1, 1322 Høvik, Norway
Location of Research	Det Norske Veritas, Veritasveien 1, 1322 Høvik, Norway
Funding Level	700,000.- NoK
Funding Source(s)	DNV Research funds
Timeframe of the Project	01.01.03 – 15.12.03
Aims and objectives of the project	This project is an integrated element of a larger research programme undertaken by DNV and Norwegian Institute of Water Research (NIVA). This programme was initiated in 2003 and will run until 2005. The overall aim is to expand the understanding associated to proposed treatment options for non-indigenous species introductions and to develop methods, standards and norms for risk reducing measures (treatment methods).
Research Methods	Literature review, laboratory studies, full scale verification studies
Results	Ballast Water Verification Protocol Standard for Certification Performance criteria – Ship/ Crew safety

Notes

Name of Paper	A proposed frame-work for approving ballast water treatment technologies
Treatment options researched	Generic
Principal Researcher(s)	Dr Doug Mountfort
Contact Details	Dr Doug Mountfort, Cawthron Institute, Private Bag 2, Nelson, New Zealand Phone: 64-03-54-82-319 Fax: 64-03-54-69-464 douglas.mountfort@cawthron.org.nz
Host Institution(s)	Cawthron Institute, Nelson, New Zealand
Location of Research	Cawthron Institute, Nelson, New Zealand
Funding Level	Approx $NZ 20K
Funding Source(s)	New Zealand Foundation for Research, Science and Technology (FRST)
Timeframe of the Project	Ongoing
Aims and objectives of the project	Despite the many technologies that are being advanced for the treatment of ships' ballast water there currently exists no satisfactory procedure for their evaluation, validation and approval. Among the reasons for this are: until recently lack of an international standard for ballast water treatment, lack of an international standard on sampling methodology, lack of agreement on what constitutes a valid range of testing organisms that can be used as an international testing standard. Despite this, new treatment technologies are being installed on ship's without having gone through stringent testing and verification protocols that would be required to meet an international standard. Our objective is to outline a framework that could be adopted in which a new technology would be evaluated, verified and certified before approval for release. Within this framework the mode of operation of a proposed international body approving new treatment technologies is described. The new framework will provide the vendor with clear pathways leading to the eventual approval of a new technology following performance review in each stage of the evaluation chain.
Research Methods	NA
Results	N/A

Notes

Name of Paper	Ballast water treatment verification protocol - DNV
Treatment options researched	*The development of a standard for certification for the approval of ballast water treatment system*
Principal Researcher(s)	Aage Bjørn Andersen (DNV), Bjørn Olav Johannessen (DNV), Egil Dragsund (DNV)
Contact Details	Det Norske Veritas
Host Institution(s)	Det Norske Veritas, Veritasveien 1, 1322 Høvik, Norway
Location of Research	Det Norske Veritas, Veritasveien 1, 1322 Høvik, Norway
Funding Level	700,000.- NoK
Funding Source(s)	DNV Research funds
Timeframe of the Project	01.01.03 – 15.12.03
Aims and objectives of the project	This project is an integrated element of a larger research programme undertaken by DNV and Norwegian Institute of Water Research (NIVA). This programme was initiated in 2003 and will run until 2005. The overall aim is to expand the understanding associated to non-indigenous introductions and to develop methods, standards and norms for risk reducing measures (treatment methods).
Research Methods	Literature review, laboratory studies, full scale verification studies
Results	Ballast Water Verification Protocol Standard for Certification

Notes

Name of Paper	The Artemia Testing System for ballast water treatment
Treatment options researched	*Physical separation (cyclone, filter), chemical treatment (oxidising agent)*
Principal Researcher(s)	Dr. Voigt Consulting.
Contact Details	Kampstr. 7 24601 Stolpe Germany Tel: +49 4326 987 37 Fax: +49 4326 987 38 Email: m.voigt@drvoigt-consulting.de Web: www.drvoigt-consulting.de
Host Institution(s)	Dr. Voigt-consulting.
Location of Research	Germany.
Funding Level	
Funding Source(s)	Contract research (consulting).
Timeframe of the Project	1998 – ongoing.
Aims and objectives of the project	To provide full-scale data for the efficiency of ballast water treatment options. Compare different treatment options.
Research Methods	Ballast water treatment options are tested at full-scale flow rates in land-based tests with a specially developed testing protocol (ATS = Artemia Testing System) for the biological efficiency of ballast water treatment options.
Results	The ATS, in combination with at least one more small (< 50µm) test species is a useful tool for evaluation of new treatment options .

Notes

Name of Paper	**Development of Dinoflagellate "Cyst-on-Demand" Protocol, and Comparison of Particle Monitoring Techniques for Ballast Water Treatment Evaluation**
Treatment options researched	*Filtration, Hydrocyclone, UV, Biocides and Photocatalysis*
Principal Researcher(s)	Dr. Jose Thomas Matheickal and Prof. Tay Joo Hwa,
Contact Details	Telephone: 65-67941556, Facsimile: 65-67921291, E.mail: jtmath@ntu.edu.sg Postal address: Institute of Environmental Science and Engineering, Nanyang Technological University, Innovation Centre, Unit 237, Block 2, 18 Nanyang Drive, Singapore 637723
Host Institution(s)	Institute of Environmental Science and Engineering
Location of Research	Singapore
Funding Level	-
Funding Source(s)	-
Timeframe of the Project	2002-2003
Aims and objectives of the project	• to evaluate the use of particle counting as a measure of ballast water filtration efficiency and to continuously monitor filter performance • to develop and optimise a culturing protocol for mass-culturing of dinoflagellate cysts
Research Methods	• lab-scale and pilot scale evaluation of filtration systems • comparison of various particle monitoring techniques using different water samples • excystment and encystment studies using dinoflagellate cultures
Results	Dramatic variations in particle counts were present between electrical sensing zone based particle counters and the commonly used light obscuration based counters. The latter one dramatically undercounted particles in smaller size classes compared with the research grade ESZ instruments for all types of samples. However, light obscuration particle counters can give a cheap and practical solution for online monitoring of ballast water, provided the instrument is calibrated using appropriate calibration standards, right concentration of particles used and correct flow rate is chosen. It is strongly recommended that ballast water monitoring be conducted using an electrical sensing zone based particle counting instrument for any verification purposes. The second part of the study developed culture protocols for producing hypnozygotes (cysts) of the CCMP1735 strain of dinoflagellate *Scrippsiella Sp.* on demand. It was observed that transferring a large biomass of motile cells to nutrient deficient media induces cyst formation. Once the hypnozygotes mature they begin spontaneously excysting after about 2 days. However, hypnozygotes can be stored in a quiescent state for up to 2 months in the dark at 5 to 7 ^{o}C, although the proportion of viable cells drops after about 1 month storage. The time to excystment of cold-stored hypnozygotes can be predicted from the time of cold storage. Dinoflagellate, being an invasive species of international concern, can be an ideal surrogate organism for treatment system evaluation. The protocol developed in this study can be used to produce sufficiently large number of dinoflagellate cysts.

Notes

Name of Paper	Test procedure for evaluation of ballast water treatment system using copepoda as zooplankton and dinoflagellates as phytoplankton
Treatment options researched	*N/A*
Principal Researcher(s)	Dr. Yasuwo Fukuyo, Capt. Takeaki Kikuchi Mr. Seiji Kino, Mr. Katsumi Yoshida
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Host Institution(s)	Marine Pollution Prevention Research Department The Japan Association of Marine Safety
Location of Research	Laboratory of Marine Technology of Kyushu-Island.
Funding Level	This project is the second component of "Research and Development of the Special Pipe System for Ballast Water Treatment".
Funding Source(s)	The Nippon Foundation
Timeframe of the Project	The project commenced in April 1999 and is ongoing.
Aims and objectives of the project	The objective of this study is to develop a specific test procedure for evaluation of a ballast water treatment system to terminate and eliminate harmful aquatic organisms in ballast water based on biological and ecological nature of the organisms in coastal waters.
Research Methods	In order to establish an appropriate test procedure, it is essential to analyze the biological and ecological features of organisms in port areas where ballast water is taken on. Seasonal change and regional difference of composition and numbers of plankton in Japanese waters were observed using several references such as Nomura and Yoshida (1997). Special attention was paid to high phytoplankton numbers occurring at red tides. Based on data obtained by the analysis of plankton nature, necessity of selection of test organisms for evaluation of ballast water treatment system was assessed. For the selection, following criteria were considered; 1) the test organisms should be available in a certain amount easily anytime and anywhere to put enough concentration in test water to evaluate the result; 2) the organisms must be found in both near-shore and off-shore waters easily, as the evaluation experiment includes a test bed test on land and a onboard test in ship; 3) the organisms should be easily differentiated its survival or fatality with high accuracy for evaluation of effectiveness of treatments. A test procedure and a standard for ballast water treatment were also designed using results of above mentioned analysis. Ballast water has not only planktonic organisms, but also small benthic ones living in bottom sediment and being re-suspended by water flow, if water is charged at shallow ports. But it is appropriate to use only planktonic organisms at first for the materials of the present study in order to simply the way of discussion. Introduction of benthic organisms such as mussel and seaweeds may be made not by transport of benthic adult organisms, but by planktonic eggs and larvae, of which numbers are usually larger more than several thousand times.
Results	As the experiment to evaluate treatment systems will be conducted at various places throughout the world under various circumstances by both test-bed and on-board tests, the procedure of the experiment should be clearly defined with special consideration to the reproductivity and reliability of the result. Use of whole planktonic organisms occurring in the areas of the experiment as test organisms for the evaluation increases difficulty of experiments themselves and evaluation of results of the experiments. While analysis of plankton composition before and after the experiment by counting only live individuals is thought to be essential and inevitable, it is practically impossible to conduct

with scientific accuracy. Diatoms, one of the major components of phytoplankton, are immobile and the change of diatom cell color may not occur in a short time, even in case the cells died completely.

The conclusion of the present study is:

1. The testing organisms for evaluation of ballast water treatment system are Dinophyceae from phytoplankton and *Maxillopoda (Copepoda)* from zooplankton. These individuals with 20μm or more in size can be used for experiments.

2. Evaluation of efficacy should be based on termination rate of the test organisms before and after treatment. Live or dead can be distinguished by shape and mobility of the test organisms.

3. In order to keep reproductivity and accuracy of the evaluation, number of test organisms in test water should be counted no less than three times.

4. Standard for treatment approval is termination rate of test organisms more than 95 %. The rate should be set higher along with the development of techniques.

Concerning the cost of experiments, it is difficult to calculate, because it varies depending on scale of experiments. Quantitative analysis (triplicate observation) of phytoplankton and zooplankton with judgment of live or dead costs US$200 per sample.

Notes

Name of Paper	Testing ballast water treatment equipment
Treatment options researched	*Not applicable*
Principal Researcher(s)	Professor Arne E Holdø
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Host Institution(s)	University of Hertfordshire
Location of Research	University of Hertfordshire
Funding Level	internal
Funding Source(s)	internal
Timeframe of the Project	End of July 2003
Aims and objectives of the project	Construction and testing of facility enabling Ballast water treatment equipment to be tested for certification/ classification
Research Methods	Fluid mechanic designs
Results	Availability of facility

Notes

Name of Paper	**Performance verification of ballast water treatment technologies by USEPA/NSF Environmental Technology Verification Program**
Treatment options researched	*Performance testing of all treatment technologies*
Principal Researcher(s)	Thomas G. Stevens, Raymond M. Frederick, Richard A. Everett, James T. Hurley, Carlton D. Hunt, Deborah C. Tanis
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Host Institution(s)	U.S. Environmental Protection Agency NSF International U.S. Coast Guard
Location of Research	Multiple locations in United States.
Funding Level	
Funding Source(s)	U.S. Environmental Protection Agency U.S. Coast Guard
Timeframe of the Project	June 2001 – ongoing.
Aims and objectives of the project	Develop and implement a program for verification of the performance of technologies designed to treat ballast water.
Research Methods	Develop testing protocol with stakeholder input, and implement testing program that will produce credible, independent data on performance efficiency and operation and maintenance requirements, and make public the results of the testing for use by purchasers, users and regulators.
Results	A draft protocol has been produced and is in review by a technical panel; the final draft will be available soon for general stakeholder (US and international) review and comment, leading to a final protocol. Pilot testing against the protocol is being planned.

Notes


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