MARTOB: A New European Community Funded Project for On-board Treatment of Ballast Water and Application of Low Sulphur Fuels

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Abstract

There is a growing concern about the damage to aquatic ecosystem caused by immigration of non-indigenous species. It is estimated that more than 10,000 million tonnes of ballast water is transported by shipping activities annually, and ballast water has been recognised as a major vector for the transplant of aquatic species across bio-geographical boundaries.

Europe has the longest coastline of all the continents in the world. Shipping trade and activities have long been a major industry in Europe. Currently, European Economic Area (EEA) ship owners represent about 40% of the world merchant fleet. 90% of the EU's external trade and 40% of trade by volume between the member States are carried by sea. As a consequence, hundreds of non-indigenous species from different parts of the world have been introduced into European waters, particularly Northern Europe, through ballast water. Although many of them have not had any serious effects on the ecosystem, some have created serious problems and incurred considerable costs in remedial actions.

This paper will describe the MARTOB project, which is partly funded by the European Commission under the 5th Framework Programme for Research, Technological Development and Demonstration Activities. The project is aimed at the assessment and development of mitigating measures and procedures for environmentally friendly shipping, i.e. ballast water management and low sulphur marine fuels. The proposed research will fulfil the development of pro-active and cost effective remedial solutions by disinfecting ballast water during loading operation and/or onboard, including considerations of ship stability, safety, and subsequent environmental aspects. The project will also assess different aspects of applying low sulphur marine fuel with respect to onboard operation and environmental impact, including fuel availability and costs.

This research will lead to recommendations of alternative solutions to the current ballast water management strategy, ie. deep sea exchanges and recommendations of best practice for verification and monitoring of compliance of sulphur cap.

1. INTRODUCTION

Under the European Union's 5th Framework Programme for RTD Activities, MARTOB was initiated to tackle issues concerned at European level on ballast water management and sulphur cap in marine fuels, including the problem of updating aliens' data in EU, treatment methods, legislation, environmental, economic, risk and safety aspects.

2. OBJECTIVES

The objectives of the proposed research are:

a) to investigate methodologies and technologies for preventing the introduction of nonindigenous species through ships' ballast water,
b) to develop design tools and treatment equipment to be used in the further development of ballast water treatment techniques,
c) to assess the effectiveness, safety, and environmental and economic aspects of current and newly developed methods,
d) to develop cost-effective (capital and operating), safe, environmentally friendly on board ballast water treatment methods which have a minimum impact on ship operations,
e) to produce guidelines for crew training and criteria for selecting an appropriate ballast water management method,
f) 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,
g) to help to facilitate the introduction of an important sulphur emission abatement measure without unintentional distortion of competition in the shipping market.

3. BALLAST WATER TREATMENT

There is a growing concern about the damage to global aquatic ecosystem caused by immigration of non-indigenous species. It is estimated that shipping activities annually transports more than ten billion tonnes of ballast water, and ballast water has been recognised as a major vector for the transfer of non-indigenous species.

There are currently three recognised types of ballast water exchange methods – the empty-refilling option, flow-through and the dilution method. Regardless of method, ballast water exchange is not likely to be 100 % effective. Shipowners and shipowner associations in Europe and world-wide are about to implement ballast water management plans to comply with various international, national and regional regulations. Thus, there is an urgent need of guidelines for ship operators to design/develop their ballast water manage plans and to select alternative treatment methods other than mid-ocean ballast water exchanges.

Alternatives to ballast water exchange should not only favour operation of the ship, *i.e.* safety, stability, and running costs, but also be effective in killing/inactivating non-indigenous species and be environmentally friendly. These are the aims of the proposed research. **[1-6]**

4. THE PROGRAMME

The MARTOB ballast water treatment work plan aims to achieve its stated objective through various tasks.

a) Data collection and proposed methods

i) Legislative update and future indication

The task will update the worldwide regulations for ballast water management and discharge control. Data available in public domains will be summarised including latest movement in the legislative sectors and a review of the status of implementation of regulative instruments in EU and other countries. Thus, future indication of regulations will be analytically presented. Special attention will be given to legislative actions in European areas.

ii) Update of aliens in European waters

This task will focus on environmental issues of European problems caused by organisms introduced through release of ballast water. It will (1) update and review studies undertaken by the Concerted Action Project (1997-1999) and the Nordic Council of Ministers' Risk Assessment Project (1997-2000), and (2) continue to build up a database of marine aliens (based, e.g. on the Baltic Marine Biologists' updated database, Jan. 2000) and ballast water discharges in European waters (Baltic Sea, North Sea). It includes an update and summary of documented issues on data available for aliens in EU waters and their environmental impact and data of the discharged ballast water volumes and origins. **[6,7]**

iii) Indirect environmental aspects and risk assessment

This part will investigate risk and safety issues related to current ballast water management methods and indirect environmental impacts of ballast water. An integrated approach to the ballast water issues, related to non-environmental aspects like economic and labour/time aspects, current management costs, distribution of costs will be given. Appropriate tools and techniques will be used to assess the non-environmental and indirect environmental impacts of ballast water treatment methods. The scope of the task will be limited to an overview assessment, as more detailed work will be done on the treatment methods selected for further testing.

iv) Current methods and limitations

This task will study current methods and their limitations. It will cover all developed methods. **[8,9]** The task will involve a literature study to assess the methods and techniques that are currently being considered or developed for ballast water treatment and management. This includes methods that are already being assessed on board ships and methods that are still under development. The literature sources include grey literature and technical reports in addition to information published in scientific journals. The assessments will cover several aspects, including:

- the range of taxa that they may be effective against
- the relative costs of treatment aboard ships
- environmental implications (e.g. energy costs, waste disposal)
- operational and safety considerations
- suitability of individual methods to different types of ship
- requirement of crew training

v) Programme of requirements for ballast water treatment

Along with the study of current methods, an investigation of advanced techniques will be conducted. This work package will focus on the advantages of the proposed treatment methods compared with current methods and define the requirements and limitations.

b) Further development and demonstration of selected methods

i) Design of system

The work will focus on the development of the techniques described earlier, i.e. high temperature treatment; biological de-oxygenation; UV/US; ozone treatment; hydrogen peroxide treatment (oxicide method) and hurdle technique.

Model testing and measurement under laboratory conditions will be essential for system optimisation and full-scale sea trials.

ii) Assessment of direct and indirect environmental aspects

Following system design and laboratory tests, environmental, economic, and safety aspects, as well as biological effectiveness will be assessed. Apposite tools will be used to assess environmental and economic effects, while a preliminary safety assessment will be applied to the new methods developed. This is a very important phase, providing an overall view of the developed methods and input for large or full-scale trial procedures and strategy.

iii) Verification of the conformity of the system design

System design, onboard installation and sea trials will have to comply with classification rules and international standards. This work will be performed in close co-operation during the design of the system. In addition to providing regulations and standards for the design of the systems, recommendations will be channelled, if required, to classification societies for modification of existing rules to accommodate the new developments in onboard ballast water treatment.

iv) Definition and strategy of large and full-scale trials

In this task, the original plans for onboard installation and sea trials will be evaluated and revised based on the results of theoretical and laboratory studies. The developed methods will also be compared with current methods, before the detailed work plan for onboard installation and sea trials is finalised.

c) Installation of large/full-scale systems and sea trials

i) Validation of system installation

This work will provide technical and classification regulatory advice to inspect the system installations. This will ensure that the test protocols and procedures, including any additional on-site modifications to the system designs, comply with classification rules.

ii) System installations and sea trials

All methods developed will be tested onboard ships except for the oxicide method, which will instead be tested in a large-scale laboratory test. The high temperature and UV/US treatments both require equipment installation before sea trials can be conducted. Ozone and biological de-oxygenation methods, on the other hand, can be realised onboard without any retrofit work on the ship. Following successful sea trials, specifications of ozone-generating equipment will be produced for commercial application, while nutrient solution for de-oxygenation can be prepared onboard from ingredients easily available anywhere in the world. However, it will probably be more practical to buy it as a ready-made solution from suppliers. The nutrient solution is non-toxic and harmless to ship and crew.

iii) Assessment of biological effectiveness and direct and indirect environmental aspects

This work includes sampling of ballast water and measuring treatment efficiency, as well as evaluation of both direct and indirect environmental aspects of the treatment methods. Priority will be given to the effectiveness in killing organisms, costs of treatment, interference with the ship's normal operation and safety of ship and crew.

d) Applications, reviews and recommendations

i) Large scale trials review

This task offers opportunities for treatment system optimisation for commercial application. Applicability and limitations of individual methods will be analysed based on the results of the trials. Methods and tools to be used for the review vary depending on the treatment method.

ii) Summary of direct and indirect environmental aspects

All treatment methods, including current methods studied will be concluded in terms of direct and indirect environmental impacts occurring in the chain of ballast water treatment. This work will produce technical and scientific data for the subsequent reviews and recommendations.

iii) Biological justification of developed methods

This section will evaluate and compare the biological effectiveness of the methods developed with existing methods studied. Advantages and disadvantages as well as subsequent biological effects and limitations will be analysed from a marine biological point of view. The results of this work will be a supplement to the conclusions and an input to the documentation and recommendations.

5. CURRENT LEGISLATION REVIEW

There are currently no mandatory global regulations addressing the prevention of biological transfer of organisms from ballast water. However, local and regional initiatives have already been introduced by a number of nations. These countries have spearheaded initiatives in developing ballast water regulations where ships are required to demonstrate that they have taken steps to prevent ballast discharges that contain 'non native, harmful species of aquatic lifeform'.

These countries, comprising of Argentina, Australia, Canada, Chile, Israel, New Zealand, United Kingdom and United States, have introduced ballast water regulations which are specific to its local geography and varies from country to country. **[7]**

In addition, the BALTIC 21 network which includes 11 countries of the Council of the Baltic Sea States (CBSS) and European Union, adopted common goals for sustainable development in the

Baltic Sea Region. Prevention of alien species introduction is part of the Baltic 21 action for sustainable sea transport (Transport Sector Action, TR 3), which so far has been focused on identification of the problem and investigation of possible ways to deal with it. The initiative commenced in 1999 and is targeted for completion in 2001.

The recent MEPC 46 meeting was held at London on 23 April 2001 and one of the issue addressed include the further negotiations on the proposed Convention concerning "harmful aquatic organisms in ballast water", provisionally scheduled for adoption at a Diplomatic Conference during the IMO 'Biennium 2002-3. The results of the meeting include:

a) Agree that Ballast Water Exchange should be regarded as an interim solution,

b) Consider with a view to its adoption at this session a joint MEPC/MSC Circular emphasising the need to consider design suggestions for ballast water and sediment management options to be taken into account when developing and building new ships.

6. CURRENT RESEARCH PROGRESS IN NEWCASTLE

University of Newcastle upon Tyne has undertaken ballast water treatment research since 1999 and has several ballast water treatment projects on thermal treatment and a combination of filtration and ultraviolet treatment.

a) Thermal Treatment

There are currently two research projects on thermal treatment of ballast water to prevent the transfer of non-indigenous species. One of the projects focused on thermal treatment onboard bulk carrier and the other is on an oil tanker.

Bulk Carrier

A typical bulk carrier (187,028dwt) equipped with auxiliary boilers. The test platform operates in the warmer regions of Atlantic and Pacific oceans and thus intake seawater temperature is assumed to be 32^{o}C. **[11]**

The proposed system utilises a two stage heating system, where untreated ballast water from the tanks are diverted to the high temperature cooling circuits and is heated up to 44^{o}C at the first stage. The ballast water is then passed through a recuperator (steam from auxiliary boiler) where it is further heated up to the target temperature of 70^{o}C to achieve target kill of non-indigenous organism at the second stage. The treated ballast water is then pumped back to the ballast water tanks and gradually cooled.

The proposed system is able to achieve a target temperature of 70^{o}C at a fixed flowrate of 435 m^{3}/hr. The running cost of such a system is estimated at £160/day while capital costs is estimated to be at £102,000. Installation cost and retrofitting are not determined, as they will vary from shipyard to shipyard.

Oil Tanker

The other project focused on a crude oil tanker that represents the majority of oil tankers. Thermal treatment discussed will concentrate on a double hull tanker. **[12]**

In this project, a typical crude oil tanker (150,000dwt) is equipped with auxiliary boilers that produce steam for operation to heat up the crude oil to increase its viscosity for transfer/discharge purposes. Steam is also utilised for other operation of other machinery (e.g. steam turbine) and other heating purposes. After going through the steam turbine, exhaust steam is condensed back into water in the vacuum condenser and returned back to the auxiliary boiler. The vacuum condenser is utilised as the source for the thermal treatment of ballast water.

The proposed system recommends that ballast water be treated during the process of intake before it is pumped to the ballast tanks. During ballasting, seawater is pumped through the sea chest into a pre-heater (55^{o}C) before entering the steam heater (vacuum condenser). In the steam heater, the ballast water is heated up to its target temperature (65^{o}C) to achieve its target effective-kill of non-indigenous organism. The treated ballast water at 65^{o}C is then re-routed back to the pre-heater and serves as its heat source before it is pumped into the ballast tanks. The treated ballast water is then allowed to cool gradually in the ballast tanks.

Seawater temperature for intake is assumed to range from 0^{o}C to 32^{o}C at a target flow rate of 2860m^{3}/hr. Space requirements for the 4 heat exchangers have been estimated at 21m^{3}. Running cost of such a system is negligible while capital cost for the pre-heater (4 plate type heat exchangers) are estimated to be £364,000. With further optimisation, the capital cost of the heat exchangers can be reduced significantly if intake seawater temperature can be increased. However, increasing intake seawater temperature also restricts the region that the ship can travel to. It has been estimated that the capital costs would reduce to £194,000 at 17.5^{o}C (intake seawater temperature) or £121,300 at 32^{o}C (intake seawater temperature). Installation cost and retrofitting are not determined, as they will vary from shipyard to shipyard.

One significant advantages of such a system allows effective treatment of ballast water at target temperature during intake before it is transferred into ballast tanks. It is not restricted by short voyages where the heating of large quantities of ballast water is slow and unable to achieve the required target temperature of effective kill due to time constraint.

b) Filtration and Ultraviolet Treatment

This research utilises commercially available filtration and ultraviolet treatment system from Optimarin. The Optimar Ballast System comprises of the Micro Kill Separator, Micro Kill UV systems and Micro Kill filter. Due to limited technical information available, it is assumed that the Optimar Ballast System could be installed in a typical bulk carrier (187,000dwt) **[13]**

During ballast intake at 435m^{3}/hr, untreated ballast water is passed through both the filtration and ultraviolet treatment system before being pumped into the ballast tanks. The primary process utilises cyclonic separation to remove larger suspended solids and micro filters to remove remaining solids in the ballast water up to a size of 50 microns. After going through the primary process, the ballast water is treated with ultraviolet radiation, which destroys or inactivates biological organisms including zooplankton, algae, bacteria and pathogens from ballast water. The treated ballast water is then diverted to the ballast water tanks.

The capital/piping cost are estimated to cost around £420,000 and does not include installation costs. Running costs are unable to be estimated as the technology is new and no data is currently available.

7. Low Sulphur Fuel Studies

Increased use of low-sulphur marine fuel has been identified as a measure for reduced sulphur emissions from shipping. As the sulphur emissions are proportional with the content of sulphur in the fuel, this measure provides increased effect with decreasing level of sulphur in the fuel.

Extension of areas where a sulphur cap is applicable will require increased availability of low sulphur marine fuels of different qualities. Slow speed engines operating on residual fuels are dominating the world-fleet, and residual fuels are the dominating fuels used.

The development of marine engine technology and marine fuel and lubrication oil qualities have many interactions, such as:

- Implications of fuel mix changes for the refineries
- Engine and fuel effects on all emission components, fuel economy and hence operating margins
- End user requirements for availability, and operability.

Due to these interactions, a co-operative test and development programme between representatives from the oil industry, engine manufacturers and end users is appropriate when introducing abatement measures affecting the fuel quality.

As shipping is an international transport mode, vessels of different flag and representing different trade will operate partly within a designated low sulphur control area. When introducing a new abatement measure in the market, the properties of the market and possibility of compliance must be considered. The effect of the abatement measure will depend on compliance from ship owners operating solely within the defined areas as well as ship owners in transit through or in/out of the defined areas.

Low-sulphur marine fuel is only available at a limited number of locations worldwide. The price of operating on low-sulphur fuel is significantly higher than operating on conventional marine fuels today. The European Commission has taken action towards a sulphur cap for marine fuels applicable for the North Sea, with limits far below the average sulphur content of marine fuels sold worldwide. Regulation affecting the refineries fuel mix will affect the market and several technical and capacity related challenges must be overcome by the refinery industry.

Low sulphur fuel and distillates are available for marine consumption today, but the amount of low sulphur fuels is limited and operation on low sulphur fuels/distillates implies higher operating costs for the ship.

There is no system available today to record or scientifically verify the sulphur content and emissions from consumption of marine bunker fuels in European waters. Present information of sulphur emission is based on compiled fuel sale statistics and world average values of sulphur content of marine fuels.

Low Sulphur Fuel Technical programme

The technical programmes for fuel studies will be realised by following:

Assessment of the world marine bunker market

The present world bunker market is based on the balance of supply and demand within the framework of requested fuel qualities. A change in the framework will affect this balance, and the applicability of forthcoming regulations of sulphur content of the fuel will depend on the supply side being able to meet the new demand with regards to crude quality and refinery infrastructure. The research will analyse the future situation of the supply side of the bunker market.

Technical aspects related to machinery and systems in the context of application of low sulphur fuels

Assessment will formed on potential technical restrains and advantages when using reduced sulphur content fuels and effects of new fuel qualities on the performance for marine engines.

Operational aspects related to operation on low sulphur fuels

The work will address cost-benefit and future challenges for the end user of requirements to use of new fuel qualities.

Verification and monitoring of compliance with sulphur cap on marine fuels

New regulations with impact on cost and operation must be implemented with uniform effect to avoid unintentional distortion of competition between operators in the market. This research will establish a recommended practice for verification of compliance with new regulations.

8. MARTOB PARTNERS

Twenty-five partners, from eight countries, will carry out MARTOB collaboratively ie. Norway, Sweden, Finland, Denmark, the Netherlands, United Kingdom, France and Greece. The consortium consists of:

- Two universities with three departments (two of them from one university) to perform scientific development: University of Newcastle (UK) and Abo Akademi University (Finland)
- Eight marine and environmental research institutes and technology developers: VTT Manufacturing Technology (Finland), TNO Environment, Energy and Process Innovation (Netherlands), TME Institute for Applied Environmental Economics (Netherlands), SINTEF Applied Chemistry (Norway), FRS Fisheries Research Services (UK), IFREMER French Research Institute for the Exploitation of the Sea (France), MARINTEK Norwegian Marine Technology Research Institute (Norway), EPE Environmental Protection Engineers S.A.(Greece)
- One classification society setting important classification rules and international standards, verification of test plans and safety aspects: BV Bureau Veritas (France)
- Three marine consultant/services involved in safety assessment, approvals of system design: Three Quays Marine Services (UK), Fueltech AS (Norway), SSPA AB (Sweden)
- Three ship owner associations, acting as a conduct for further contact with ship owners for sea trials: INTERTANKO The International Association of Independent Tanker Owners (UK), ICS International Chamber of Shipping (UK), Norwegian Shipowner Association (Norway)
- Three ship owners who are the end users of the research results and provide facilities for trials: Souter Shipping Ltd (UK), Wallenius Wilhelmsen Lines (Norway), ABC Association of Bulk Carriers Ltd (UK)
- One engine manufacturer providing technical data on engines using low sulphur fuel: MAN B&W Diesel A/S (Denmark),
- Three equipment manufacturers contributing to technologies and further development: Berson Milieutechniek B.V. (Netherlands), V/den Heuvel Watertechnologie BV (Netherlands), Alfa Laval Marine & Power AB (Sweden)
- One oil company offering technical advice, data and experience of low sulphur fuel studies from supply to market: Shell Marine Products (Norway)

9. CONCLUSION

The ballast water regulation has been on the table for some years and could take more time to resolve. As such, more and more countries have adopted local ballast water regulations to prevent the introduction of alien invasive species to their waters. It is with optimism that a foolproof water ballast management programme that is agreed by all, could be reached within the near future.

With the completion of MARTOB programme, it is envisaged that the results of this programme 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.

In addition recommendations resulting from this programme of research on ballast water management would provide another source of information to various international organisations like IMO, ICES, IOC and other maritime organisations, marine environment agencies and regulatory bodies.

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