A Note on Some Important Marine Environmental Issues

Martin Renilson

Renilson offers a review of a broad range of environmental issues facing the maritime community.

Who should read this paper?

Anyone with an interest in the maritime environment will find something of interest in this paper. The maritime environment is of ever increasing importance to the entire maritime community. Those who are not experts in a particular field of environmental science will benefit from an overview of key issues, while specialists in environmental science will gain a broader perspective on the full range of issues.

Why is it important?

To ensure that the effect of man's exploitation of the ocean environment is minimised, and does not have catastrophic consequences in the long term, significant research is required in order to find solutions to the issues raised.

This paper is a summary of the key issues of importance to the maritime environment. Sequestration of CO_2 in the oceans has been suggested as one possible approach to alleviating climate change caused by burning of fossil fuels. Accidental spillage of oil into the ocean from ships, drilling and production activities and land-based sources (run-off) pose a significant threat to marine ecosystems. Waste disposal at sea has a detrimental impact on the ecological, economic, cultural, recreational and aesthetic values of the marine ecosystem. Noise pollution is becoming an important environmental concern as activity at sea continues to grow. Vessel generated waves can cause serious erosion damage to coastal areas. And disposal of ships at the end of their useful lives requires a greater understanding of the large number of hazardous materials typically on-board and how to dispose of them safely. For each of these challenge areas the author outlines the state of the art, and points to areas where there is a need for more work. A broader understanding of the issues across a wide range of environmental topics will, hopefully, lead to a clearer perspective and synergy of action by the maritime community.

About the author

Martin Renilson is Professor of Hydrodynamics at the Australian Maritime College, Tasmania, Australia, and was formerly Technical Manager and Deputy General Manager of the Maritime Platforms and Equipment group in QinetiQ, UK. Professor Renilson is President of the Engineering Committee on Oceanic Resources (ECOR).

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Martin Renilson

Australian Maritime College, P.O. Box 986, Launceston, Tasmania, Australia, 7250, Email: M.Renilson@AMC.edu.au

ABSTRACT

This paper discusses the effect of the following on the marine environment: CO_2 storage in the oceans; oil pollution; waste treatment; hydro-acoustic noise; vessel generated waves; atmospheric emissions from vessels; and finally vessel disposal at end of life.

INTRODUCTION

Man's use of the seas is having a major contribution to both global climate change issues, and the ocean environment in particular.

Important examples in the marine environment are: CO_2 storage in the oceans; oil pollution; waste treatment; noise; vessel generated waves; emissions from ships, and finally vessel disposal at end of life.

The 1982 United Nations Convention on the Law of the Sea establishes duties in respect of the pollution of the marine environment from any source. In addition to this, the 1972 Convention of the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (MARPOL) addresses marine pollution.

CO_2 STORAGE IN THE OCEANS

The effect of CO_2 emissions due to the burning of fossil fuels on the world's climate is generally accepted, although the seriousness of this is still in some debate. One strategy to minimize this is to find ways to sequester CO_2 into the ocean.

There are two approaches to CO_2 ocean sequestration: direct injection; and ocean fertilization. Both require further research, however at this stage direct injection is more promising. With direct injection one of the problems is the impact on marine life close to the injection points before the CO_2 is diluted into the ocean, and hence there is a pressing need to collect data on the damage caused by CO_2 [ITTC, 2005].

The two methods of direct injection of CO_2 are: middle depth dissolution; and deep bottom storage. The density of liquid CO_2 is larger than seawater below about 3000m, so the depth at which the discharge is made governs the behavior of the liquid CO_2. Discharge above this depth results in the formation of droplets that dissolve as they rise to the surface. The dissolution rate and the rise velocity of the droplets govern the depth necessary for complete dissolution. To obtain large dilution, one option is to use a ship towing a pipe more than 2000m long [Ozaki, 1997].

Liquid CO_2 droplets injected below this depth sink and settle into seabed hollows to form CO_2 lakes. These are covered by hydrate film that suppresses the dissolution rate of the CO_2, and hence these lakes are likely to remain for quite some time. The ecosystems in the lakes are destroyed, however it is not clear what the effect on the ecosystems close to the edges of these lakes will be [Omerod and Angel, 1996].

There are a number of different numerical models for predicting CO_2 transfer in the ocean, and a variety of ocean scale simulations have been conducted, ranging from studies in the near field to determine the behavior of the droplet plumes, and diffusion of dissolved CO_2, to ocean scale simulations to predict the time period of sequestration and mixing for periods of hundreds of years [ITTC, 2005].

OIL POLLUTION

Use of the sea has lead to concerns about oil pollution, mainly due to spillage following accidents, both for fuel and oil as cargo. It is important to realize, however, that there is a significant input of oil into the ocean environment from other sources.

A breakdown of the data from the three principal source categories indicates that vessel source spills far exceeds the inputs from production and land based sources combined, representing over 68% of the total input. The next largest source is land based, at 23%, with production representing the smallest input by volume: 9% [ITTC, 2005].

Oil pollution from vessels falls into two categories: accidental spills (groundings and collisions); and operational discharges (oil discharged from tank cleaning *etc*). About one third of the oil that gets into the ocean environment from vessels is from accidental spills, with roughly two thirds from operational discharges [ITTC, 2005].

In the1990's, accidental spills of oil totaled almost 105,000 tonnes/year, with nearly 89,000 tonnes from tankers, 2,600 tonnes from barges, 5,600 tonnes from non tanker vessels, 4,600 tonnes from onshore pipelines, 2,700 tonnes from onshore facilities and 400 tonnes from offshore exploitation and production activities [Etkin, 2001].

The environmental impacts of oil spills can vary from minimal, to the death of everything in a particular biological community. Oil spills can impact fisheries resources either directly or indirectly. Direct impacts can be lethal, and include tainting, or interference with fishing activities, while indirect effects are due to the effect on the food chain.

Concerns are often raised about possible long term effects, however detailed post-spill studies have shown that many components of the marine environment are highly resilient to short term adverse changes in the environment, and as a consequence a major oil spill will not always cause permanent effects [ITTC, 2005].

Heavy fuel oil has high density and high viscosity. This means that it has a tendency to sink, and presents particular challenges for clean up operations.

Over the past 25 years about 40% of the 450 ship - source oil spills attended on site by the International Tanker Owners Pollution Federation have involved medium or heavy fuel grades. Each of the most significant incidents over the last 10 years have involved spills of heavy fuel oils, including *Nakhodka* in Japanese waters, *Baltic Carrier* in Danish waters, *Erika* in French waters, and *Prestige* in the North Sea [ITTC, 2005].

Spilled oil that finds its way into sediments on the seabed may persist for many years as degradation processes are likely to be slow in deep, cold waters [ITTC, 2005].

There are three main responses to oil spill at sea as shown in Table1, taken from information presented in ITTC [2005], and Obe [2000].

Table 1: Approaches for responses to oil spills at sea
(from information presented in ITTC [2005], and Obe [2000])

Approach	Description	Comments
Containment and recovery	Floating booms are used to contain and concentrate oil prior to its recovery by special skimmers.	This prevents the natural tendency of the oil to spread, fragment and disperse. By the time that ship borne equipment can be implemented, the oil will be very thinly spread. Wind, waves and current will limit the effectiveness of the systems, and there are limitations on the pumping of viscous oils.
Application of dispersants	Dispersants are spread on the surface of the oil to break it into small droplets that dilute to concentrations below that likely to cause damage.	In many countries the use of dispersants is limited on environmental grounds. The probability of significant damage caused by dispersed oil droplets compared to that caused by untreated floating oils slicks have to be compared.
In situ burning	The oil is concentrated by fire resistant booms and set alight.	It can be difficult to collect and maintain oil at sufficient thicknesses to burn. Ignition can be difficult as most flammable components of the oil evaporate quickly. Residues from the burning may sink, with potential long term effects on the seabed ecology, and there may be health and safety issues related to the atmospheric fall out from the smoke plume. There is also the concern that the fire might spread out of control.

Waste disposal at sea has been a major contributor to maritime pollution, particularly in restricted and busy waterways. This destroys the ecological, economic, cultural, recreational and aesthetic values of the marine ecosystem and its components [Laist, 1997].

Not all marine debris is generated by ships. The main land based sources are combined sewer overflows, storm drains that empty directly into the sea, solid waste and landfills from industrial activity. This paper will, however, deal only with maritime sources.

Until recently, the most common disposal method was to off-load the solid waste, not including plastic, overboard. It was generally considered that the oceans are capable of dealing with raw sewage through natural bacterial action.

However, MARPOL legislation now prevents the off-loading of waste materials from ships within 12 miles of the shore unless they have in operation an approved treatment plant. In some special areas, such as the Great Barrier Reef, and the Gulf of Oman, it is completely prohibited. In addition, various countries are introducing their own local legislation governing waste management from ships. Hence, this method of disposal is becoming less and less of an option for many vessels.

The storage of waste for long periods on board presents a hazard because of the inherent health risks, and dangers associated with the increased pressure due to bacterial gas build up. There is also the problem of the space this takes up and the drudgery associated with handling the waste, which is becoming an increased problem for some operators.

Hence, an efficient clean process that destroys and reduces waste is becoming important, and being investigated by a number of organisations. The different technologies associated with the various waste streams is given in Table 2.

Table 2: Waste streams and associated technologies

Waste Stream	Description	Technology
Solid – Plastics/Medical/Food/Paper/Cardboard	General/Galley waste	Incineration/Pyrolysis Catalytic Wet Air Oxidation Ash Removal
Solid – Food	Galley waste	Microwave/Screw Press
Liquid – Oily Water	Bilge water	Ceramic Oily Water Separator and Catalytic Wet Air Oxidation
Liquid – Black Water	Sewage	Membrane Bioreactor and Catalytic Wet Air Oxidation
Liquid – Grey Water	Laundry and Shower Waste	Membrane Bioreactor and Catalytic Wet Air Oxidation
Liquid – Ballast Water	Sea Water Used as Ballast	Ballast Water Technology[1]
Hazardous Waste	Solvents, Batteries	Disposed of Ashore

[1] *Ballast water technologies are still developing.*

Although new ships can be, and often are, fitted with appropriate waste treatment and storage facilities, many existing ships lack such capabilities. Considerable thought is being given on how to retrofit Integrated Waste Management Technologies in Royal Navy (RN) warships [Hughes and Stevenson, 2005]. RN ships have less space for equipment and storage compared to cruise ships, have fewer personnel and generate less solid waste. Retention of seagoing staff is a critical issue, and the drudgery associated with handling waste is a strong disincentive to remain at sea.

In addition, warships do not have a planned route, so may not be able to take advantage of scheduled port stops to offload waste.

An ever more important consideration for warships is the desire to be as independent from port as possible, to limit the possibility of terrorist attack, and this is also a strong driver to be able to process waste on board.

Whilst military vessels are exempt from the MARPOL legislation, in 1996 Special Working Group 12 of NATO commissioned an Industry-led Advisory Group (NIAG) to conduce a feasibility study to assess both current and emerging technologies when applied to treating waste at sea [NAIG, 1996]. The targets set by NAIG are more stringent than the most severe local legislation. These are considered by the RN as the most appropriate targets to meet, or exceed, with respect to marine waste water treatments [Hughes and Stevenson, 2005].

HYDRO ACOUSTIC NOISE

Hydro acoustic noise pollution is becoming an important environmental concern [Heathershaw *et al*, 2001]. The implications of this are not particularly well understood, and are often largely undetectable other than to the specialist.

Little is known about the full consequences of noise pollution for the marine environment, and for cetaceans in particular. As a consequence, it is difficult to introduce legislation, or even voluntary codes of practice.

The Marine Mammal Protection Act in the US is currently under review and it is expected to include specific measures for marine mammal protection from noise pollution [Simmonds *et al*, 2003].

Ambient noise comprises two aspects: continuous noise and impulse noise. Continuous noise is characterized as a spectrum level, which is the level in a 1 Hz bandwidth, and is usually given as intensity in decibels relative to a reference level of one micro Pascal. Impulse noise is transient and generally of wide bandwidth. It is characterized by peak amplitude and repletion rate [Harland *et al* 2005].

Of course there will be a natural ambient noise level due to wind, wave action, shore/surf, precipitation and spray. In addition to this, vessel traffic noise will dominate in certain areas and can be classed as ambient noise. Vessel traffic noise is most evident in the 50 – 300 Hz frequency range. At longer ranges the sounds of individual ships merge into the background [Harland *et al* 2005].

There has been a large increase in ambient noise in recent years, particularly in the Northern Hemisphere [Simmonds *et al*, 2003].

It has been noted that the noise from a super tanker can be detected over 450km away (Ross, 1976). Paradoxically, quieter, faster vessels can cause more problems to cetaceans than slower larger ones, as the noise may only rise above the ambient level a short time before contact, provoking a 'startle' reaction [Simmonds *et al*, 2003].

Civilian sonars such as echo sounders and fish-finders can make a major contribution to the ambient noise level.

Most vessels from small leisure craft up to large commercial ships operate at least one echo sounder, and commercial fishing sonars in particular make a major contribution to the ambient noise because of the higher power directed horizontally [Harland *et al* 2005].

Seismic surveys, using high intensity low frequency sounds, can cause significant hydro-acoustic noise. Depending on the type of survey, this can cause localized activity, subjecting resident fauna to high levels of sound for protracted periods, and may consequently have significant long term effects [McCauley, 1994].

Noise is generated by industrial activity including oil and gas production, dredging and port developments. This can be in the form of short term activity such as installation or permanent activity such as that associated with oil production.

In addition, onshore industrial activity and transport systems close to a coastline can generate underwater noise [Harland *et al* 2005].

Military activities are also a source of underwater noise which often receives severe criticism. In particular, active sonars, which are designed to focus as much energy as possible in specified directions are of concern. There have been reports of mass strandings of cetaceans following major military exercises [Simmonds *et al*, 2003].

Marine wind farms, wave energy devices, and marine current turbines all have the potential to generate additional underwater noise. These are all relatively new devices, and as yet their total contribution to the ambient noise is uncertain, however it is likely that their impact will increase in the future.

Cetaceans, and other fauna generate their own sounds for purposes ranging from group recognition and mating to stunning of prey.

Considerable effort is required to determine the background noise levels prior to acceptance of new developments and this will be an important element of future work for environmentalists.

VESSEL GENERATED WAVES

Vessel generated waves can cause serious erosion damage to river banks, as well as causing considerable disturbance to other water users [Renilson and Lenz, 1989; Nanson *et al*, 1994].

Nowadays many authorities responsible for managing waterways impose criteria on new vessels to prevent them from generating damaging waves [Macfarlane and Renilson, 1999] and a number of specialist vessel designs have been developed principally to reduce the impact of the wave generated, which is not as simple as wave height. This aspect of the design and operation of high speed vessels will become more important in the future.

When a vessel is traveling in shallow water the wave wake it generates is influenced by water depth. In addition, as the wave propagates from the water depth into the shallower water close to the shore the effect of the shoaling bottom will modify the wave system. Both these factors add a considerable complexity to the study of vessel generated wave wake, and need to be taken into account when assessing the impact of vessels close to the shore [Doctors *et al* 1991].

ATMOSPHERIC EMISSIONS

Until recently, airborne pollution from ships has gone largely unregulated, possibly partly because shipping has been identified as an efficient means of transporting goods. CO_2 emissions per tonne kilometer for a large cargo vessel are less than 30% of that from the most efficient heavy truck. [Swedish NGO Secretariat on Acid Rain].

However, the importance of marine based emissions to the overall air pollution is becoming recognized. For example, in Europe at the end of 2004 cargo vessels emissions exceeded heavy truck emissions of particulate matter (PM) by 4-6 times, SO_2 by about 30-50 times, and NO_x by about 2 times (comparing emissions in terms of units per tonne-kilometer).

Greenhouse gas emissions from ships has been investigated by the IMO [Henningsen, 2000] and the Intertanko organization has recently submitted a proposal to MARPOL suggesting changes to deal with NO_x [Intertanko 2006].

Ships are responsible for roughly 2% of global CO_2 emissions. [Corbett *et al,* 1999].

Ship emissions contribute to numerous adverse environmental impacts including: human health; acidification; eutrophication of terrestrial and coastal ecosystems; damage to vegetation; increased corrosion to buildings and materials; and regional haze.

Worldwide, NO_x emissions from ships have been estimated at about 10 million tones per annum, equivalent to about 14% of the total NO_x emissions from fossil fuels.

Most engine manufacturers are producing standard engines which comply with the MARPOL NO_x limits, although this results in a slight increase in fuel consumption. Engine manufacturers are now aiming for much greater NO_x reductions, along with reduced fuel consumption and smoke, which can be possible by better understanding and tuning the combustion process. For example, delayed injection timing is very effective in reducing NO_x, but increases fuel consumption and smoke. This is an area where additional research is required [Goldsworthy, 2002].

VESSEL DISPOSAL AT END OF LIFE

The need to dispose of ships in an environmentally friendly manner at the end of their lives is becoming recognized as an important environmental issue. This is usually done in an approved recycling yard.

The shipping industry has an obligation to minimise the safety and environmental problems associated with the disposal of ships, and one way to help in doing this is to monitor the potentially hazardous materials that are used in the construction or equipment on ships, as well as completing an inventory of hazardous substances on board ships before they arrive at the recycling yard.

In March 2004 IMO Resolution A.963(23) developed a Green Passport which is a paper based document that records all hazardous materials and tracks the hazardous contents of a vessel from inception through to disposal. The passport is designed to be completed by shipbuilders for new build vessels, and by classification societies for existing ships. Hazardous materials are categorized in the manner shown in Table 3.

The RN has developed a software tool version of the Green Passport. This can be used to:

- identify the material removal requirements for a ship breaker;
- define the presence of all hazardous materials for a prospective buyer; and
- verify material removal prior to the use of a vessel as a target, where appropriate.

The RN Green Passport provides a complete listing by weight and location of the materials contained in the vessel that are suitable for recycling. It categorizes various degrees and types of materials within specified compartments, and hence can produce a report of total weight for the purpose of recycling.

Class	Definition	Typical examples
Class A	Hazardous material incorporated within the ship structure such as deck machinery, auxiliary systems, cooling ducts, exhaust pipes and ventilation systems.	Asbestos, lead based paints or plastics, PCBs, antifreeze compounds, engine additives, kerosene, hydraulic oil, epoxy resins radioactive materials.
Class B	Operationally generated waste products. .	Ballast water, raw and treated sewage, garbage, debris, oily waste, cargo residues, bunkers, lubricating oil, hydraulic oil, grease.
Class C	Materials in the ship's stores.	Gasses such as halon, bottled oxygen, de-ioniser acids, de-scalers.
Class D	Materials in aircraft and boats.	Plastics, engine additives, hydraulic oil, epoxy resins, grease.
Class E	Materials associated with weapon systems.	
Class F	Materials which may be recycled prior to decommissioning.	Cadmium lead, mercury, arsenic.

Table 3: Categories of hazardous materials

CONCLUDING COMMENTS

This paper has briefly discussed a number of the environmental issues facing the marine community.

To ensure that the effect of man's exploitation of the ocean environment is sustainable, significant research is required in order to better understand and find solutions to the issues raised.

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