Students’ Edition of BRINICLE
in Collaboration with
IIRE JOURNAL
of
MARITIME RESEARCH & DEVELOPMENT (IJMRD)

ISF Institute of Research and Education (IIRE)

MARCH 2019
INDIAN MARITIME UNIVERSITY
MUMBAI PORT CAMPUS
(Marine Engineering & Research Institute, Former D.M.E.T.)

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Maritime sector has always been influencing the global economy. Shipping facilitates the bulk transportation of raw material, oil and gas products, food and manufactured goods across international borders. Shipping is truly global in nature and it can easily be said that without shipping, the intercontinental trade of commodities would come to a standstill.

Recognizing the importance of research in various aspects of maritime and logistic sector, IIRE through its Journal of Maritime Research and Development (IJMRD) encourages research work and provides a platform for publication of articles, manuscripts, technical notes, papers, etc. on a wide range of relevant topics listed below:

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ABOUT INDIAN MARITIME UNIVERSITY – MUMBAI PORT CAMPUS

Indian Maritime University – Mumbai Port Campus comprises of two premier institutes, Lal Bahadur Shastri College of Advanced Maritime Studies and Research (LBS CAMSAR) & Marine Engineering and Research Institute (Former D.M.E.T.). LBS CAMSAR is the post sea training institute whereas MERI Mumbai is the pre – sea training institute.

LBS CAMSAR was founded in October, 1948 under the recommendations of the Merchant Navy Training Committee as Central Government premier post sea training institute for Merchant Navy Officers of Navigation & Engineering. And since then, it is offering the comprehensive range of courses for Merchant Navy Officers.

Marine Engineering and Research Institute (M.E.R.I.), formerly known as Directorate of Marine Engineering Training (D.M.E.T.), was established in the year 1949 by the Govt. of India, when the need was felt to train Marine Engineers separately. And since then, it is imparting the education and training to the cadets with a goal of producing the best marine engineers and nautical officers for the world with adopting the latest technology to meet the latest and demanding requirements of the shipping fraternity.
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MESSAGE FROM THE CONVENER

It is very heartening to note that Indian Maritime University – Mumbai Port Campus (Marine Engineering & Research Institute) is organizing a two days Technical Fest Brinicle in association with Maritime Training Trust, D.G Shipping on 28th & 29th March, 2019. This fest is an initiative taken by Maritime Training Trust with an objective of enhancing the maritime knowledge of the participants and to provide all the stakeholders of Maritime Industry an opportunity to gain a great deal of insight into the “emerging technologies”.

I am thankful to IIRE Journal of Maritime Research and Development for collaborating with us. It is pleasing to note that the twelve accepted papers dwell on maritime subjects ranging from Artificial Intelligence, IoT, Inland waterways in India, Sustainable Development, which will dominate the industry in the coming years.

As the success of the event depends ultimately on the people who have worked in planning and organizing it, so I would like to thank the members in all the committees for their great efforts on this success.

Hare Ram Hare
Convener, Brinicle
Editorial

IIRE efforts to ingrain culture of research continues unabated.

A specific seminar is planned in March 2019 at Mumbai bringing researchers, industry and academia together to discuss and highlight the importance of research in the maritime sector.

Yet another opportunity arose when the Indian Maritime University – Mumbai Port Campus invited IIRE to collaborate in the presentation and publication of research based papers of their young cadets pursuing graduate maritime courses. Twelve papers were selected after a process of review which are now being published in a Special edition of the IIRE Journal of Maritime Research and Development. It was heartening to see papers dwelling on some contemporary themes like, Technology inroads into shipping, Sustainable Shipping, Coastal & Inland Waterways that is finding lot of thrust in India. Block-chain technology, Artificial intelligence, Energy efficiency are the areas covered in some of these selected papers. Papers chosen for publication in the Journal was the reward propagated and this brought in much encouragement and healthy competition. The moot idea was once again to engrain the discipline of research in the impressionable minds of the young cadets finding their sea-legs in a dynamic and highly operationalized and challenging shipping environment.

Dr. (Capt.) S. Bhardwaj \textit{fics, fni, fcmni}
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Abstract
When thinking about the future, envisioning healthier environment and cleaner surroundings is most desirable. That goal can only be achieved by meticulously adopting the principles of sustainability in every way possible. Sustainability is all about utilizing available resources in an environmentally-conscious way and without any form of exploitation, thus greatly minimizing the chance of leaving behind any harmful footprints from our activities. Shipping, being the major means of transporting goods from country to country needs to imperatively, become as sustainable a procedure as possible. The United Nations’ 2030 agenda for sustainable development enlists 17 Sustainable Development Goals, one of them being “Conserve and sustainably use the oceans, seas and marine resources for sustainable development”\(^1\) and another one being “Take urgent action to combat climate change and its impacts”\(^1\). This paper aims to focus on these two specific goals by discussing two innovative methods. The first one is with regards to oil spills and how a specially manufactured cotton batting can help alleviate the negative impact of one. The second one is about reusing scraps from ships that are being dismantled, producing iron-based compounds from those scraps and dispersing those (safe) compounds into the ocean to boost the growth of phytoplankton which will then be able to absorb more carbon-dioxide from the atmosphere and bring the levels of carbon-dioxide, down.

Keywords: Sustainability, shipping, oil spills, carbon dioxide, cotton, phytoplankton, ocean fertilization, sequestering, climate change, marine

1. OIL SPILLS:

1.1. Introduction:

Oil spills are highly damaging occurrences in the world of shipping. An oil spill is the release of fuel or oil into the environment, especially the marine ecosystem from vessels sailing on it and is a serious form of pollution. The lives of people living close to the area where an oil spill occurs are disrupted, a large sum of money is spent on clean-up operations and the surrounding marine life undergoes devastation as well. These points make it clear that oil spills are best, avoided. One of the major reasons an oil spill becomes difficult to clean is that there is usually a large time delay between when an oil spill occurs and when the clean-up operation starts. Factors such as the ocean currents, wind and sunlight can cause the oil to spread or concentrate in unexpected

\(^1\) “IMO and Sustainable Development Goals” (2012)
patterns. Therefore, an immediate step is required that can, in a very short amount of time, control the spread of the spill.

1.2. Action of cotton batting:

A large batting (a thick, layered sheet) of specially manufactured cotton of appropriate size and weight can be designed to be released from the body of the ship at the very moment an oil spill occurs. The material that is to be used to clean up an oil spill should soak up the oil and not the water. The naturally waxy coating of cotton allows it to have a property by virtue of which it repels water and absorbs oil. The best results can be obtained when three actions occur simultaneously, namely adsorption, absorption and capillary action. The cotton can let some of the oil cling to the surface of its fibres through adsorption, allow the oil to seep into the structure of the fibre through absorption and finally allow a substantial quantity of the oil to be collected within the thin fibres, in channel like spaces, through capillary action. The last step i.e. capillary action cannot be effective unless and until the fibres are free and detangled. For this, specially combed or ‘carded’ cotton has to be used. A carding machine has rows of prongs that can stretch the fibres straight and separate them from one another. Low grade cotton that is not mature works 7 percent better than refined cotton because of the comparatively waxier nature and the finer quality of the immature cotton fibres. Low grade cotton is cheaper so this method is cost effective. Since the batting, with oil in it will have a mass lesser than that of an equivalent volume of water, the cotton structure will stay afloat. Ideally, this type of a batting can absorb 50 times its weight in water. From the charts below, an idea of the average amount of oil spilled by a vessel can be calculated, which comes to 5-7 tonnes. Based on those calculations, the weight of cotton required to be kept on board an average oil-carrying ship can be estimated to be anywhere between 100-150 kilograms. This weight will be divided amongst four or five batting-structures, each weighing 25-40 kilograms.
Number of oil spills from tankers worldwide, 1970–2016

The bars show the number of oil spills per year. Smaller oil spills (>700 Tonnes) in blue and large oil spills (>7000 Tonnes) in orange.

Quantity of oil spilled from tankers worldwide, 1970–2016

Data sources: International Tanker Owners Pollution Federation (ITOPF) for the number of oil spills, United Nations Conference on Trade and Development (UNCTAD) for trade data.
The interactive data visualization is available at OurWorldInData.org. There you find the raw data and more visualizations on this topic. Licensed under CC BY-SA by the author Max Roser.
1.3. Placement of cotton batting:

The batting can be held through a system of metal chains attached to the hull of the ship, where it will be rolled up and covered with heat and water resistant plastic so as to protect it from the effects of the sun and wind. The design of the batting, covering and chains will be such that when released during an oil spill, the entire arrangement will unfurl from its position on the hull as a composite structure made of three sections. The topmost part will have the metal chains connected firmly to the protective plastic covering (making up the second section) which will in turn, be attached to the upper part of the cotton batting. These metal chains will be fastened to a ring on the hull but will also be detachable in nature. The chains and the plastic cover, when unrolled will almost equal the entire height of the hull so that all of the batting can be dropped onto the free surface of water, thus optimizing its utilisation. The plastic cover will have slightly extended, firm and curved edges so that when the cotton batting is rolled up the two ends of the cylindrical rolled-up structure do not remain exposed.

To secure the batting when it is rolled up, an additional set of chains fixed to the hull of the ship (at a position below the rolled-up batting) will lock in with the chains that are a part of the composite structure.
1.4. Release and lifting of the batting:

To release the cotton batting into the water, the locking mechanism of the chains needs to be opened, after which the unfurling will take place. However, before releasing the lock between the chains, it is important to free the upper metal chains (that are a part of the composite body) from the ring on the hull and then tightly fasten the loose ends of those chains, to the rope(s) from one or more mooring winches. The ropes from the mooring winches can be guided by pulleys to lead to the edge of the deck, where the chains are. The point at which the chains start must be within comfortable human reach, from the deck. Once the oil has been soaked up, the whole body can be lifted with the help of the winch, brought on deck and stored on board.
1.5. Advantages over other methods of cleaning spills:

By opting for this method to clean up an oil spill, one guarantees immediate containment of the situation, foregoing any time delay. Very minimal training is required for the members of the crew to learn the procedure to execute this operation. While booms can stop oil from spreading, a strong wave can easily cause oil to be dispersed. On the other hand, in this method, the oil will be trapped in the batting which will decrease leakage. Dispersants have been known to be harmful to the environment. Cotton does not produce any such effects.

2. REDUCTION OF ATMOSPHERIC CO₂:

2.1. Introduction:

Ocean being the natural reservoir of carbon, stores about 20 times more carbon than terrestrial biosphere and soil and 55 times the carbon in atmosphere. However, this difference had dropped heavily due to the increase of CO₂ in atmosphere resulting in Green House Effect. Thus there is a clear need for the reduction in greenhouse gas emissions in parallel with internationally agreed targets to reduce the rate of climate change, necessitating the implementation of clean energy technologies. According to the Intergovernmental Panel on Climate Change (IPCC), iron fertilization of the oceans may be potential way for maintaining the CO₂ level in the atmosphere by stimulating
the growth of phytoplankton and thereby sequestering CO$_2$ in the form of particulate organic carbon.

As per agreed by the Parties to the London Convention and London Protocol for the purpose of Resolution LC-LP.1 (2008) on the Regulation of Ocean Fertilization, ocean fertilization is defined as, “Any activity undertaken by humans with the principal intention of stimulating primary productivity in the oceans, not including conventional aquaculture, or mariculture, or the creation of artificial reefs and does not involve the activities which cause the fertilization as a side effect” $^2$.

2.2. Concept of Ocean Fertilization:

“Give me a half tanker of iron, and I will give you an ice age.” John Martin $^3$

Gases are readily exchanged across the air-sea interface due to differences in the partial pressure of CO$_2$ between the ocean and the atmosphere. Temperature, salinity and biological activity can all influence the partial pressure of CO$_2$. For example, the uptake of CO$_2$ by marine algae during photosynthesis creates a shortage of CO$_2$ in surface ocean waters, driving the dissolution of CO$_2$ from the atmosphere into the surface ocean to restore the equilibrium. As a result of this and other processes, the ocean absorbed approximately one-third of the CO$_2$ released from all human activities between 1800 and 1994, leading to an increase in the total inorganic carbon content of the oceans in the range of 112 to 118 Gross Tonnage during this period.

In order for ocean fertilization to lead to climate change mitigation, three criteria must be met: (a) ocean fertilization must lead to increased growth of phytoplankton, packaging carbon and nutrients together into organic material; (b) this organic material must be transferred into the deep ocean so that it does not simply get recycled near the surface releasing its carbon back to the atmosphere; and (c) this transfer of carbon from the surface ocean to the deep ocean must result in a compensating transfer of carbon from the atmosphere into the surface ocean.

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$^2$ “Regulation of Ocean Fertilization” (2008)

2.2.1. **Understanding the Carbon Cycle:**

A part of the ocean, i.e. from surface to 200 metres deep sufficiently receives enough sunlight to support photosynthesis by marine plants, termed the “euphotic zone.” Macro algae and rooted plants are restricted to shallow coastal waters, while phytoplankton is the dominant form of plant in the open ocean. Using sunlight and dissolved inorganic nutrients as source of energy, phytoplankton convert dissolved inorganic carbon (DIC) (bicarbonate ions, dissolved CO$_2$ and carbonate ions) in seawater into organic matter through photosynthesis, driving global marine food webs and inducing the “drawdown” of additional carbon dioxide from the atmosphere.

![Ocean Ultra long term carbon cycle](image)

2.2.2. **Iron in the ocean:**

Major sources Fe in water bodies are river run-off; the resuspension of bottom sediments in coastal ocean environments; melting sea ice; atmospheric deposition of dissolved iron; and iron-rich deep water by vertical mixing and upwelling processes. Windblown terrestrially derived dust, mainly from the great deserts of the world, is a major source of external Fe input for the open oceans. Dust particles are transported over thousands of kilometres, creating strong deposition gradients across the oceans. Even volcanic ash is a major source of iron for ocean.
Contemporary ocean observations support the theory that natural iron fertilization elevates biomass. Separate multidisciplinary studies around the Crozet Islands and the Kerguelen plateau in the Southern Ocean observed elevated biomass, and also elevated export of carbon to the deep sea, in response to natural iron inputs.

2.2.3. **Iron Fertilization:**

Iron fertilization is the intentional release of Fe in low iron content areas in ocean to increase the growth of phytoplankton in order to draw carbon out of the atmosphere and into the ocean. The method sequesters or store atmospheric carbon, which is currently contributing to the greenhouse effect and global warming.

However, the method must be used in the specific regions called **High Nutrient, Low Chlorophyll (HNLC)** in large water bodies. HNLC regions cover 20% of the world’s oceans in three major areas: PACIFIC OCEAN, SUB-ARCTIC PACIFIC OCEAN, and SOUTHERN OCEAN.
2.3. Major Experiments:

Many scientific iron fertilization studies have been undertaken, between 1993 and 2019 in polar, sub-polar and tropical High Nutrient, Low Chlorophyll (HNLC) areas. These are:

1. IronEx I, 1994
2. IronEx II, 1996
3. SOIREE (Southern Ocean Iron Release Experiment), 2000
4. EisenEx (Iron Experiment), 2000
5. SEEDS I (Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study), 2001
6. SOFeX (Southern Ocean Iron Experiments - North & South), 2002
7. SERIES (Subarctic Ecosystem Response to Iron Enrichment Study), 2002
8. EIFEX 2006
9. FeeP, 2004
10. SAGE, 2004
11. SEEDS-II, 2004
12. EIFEX (European Iron Fertilization Experiment)
13. Haida Salmon Restoration Corporation (HSRC), 2012
14. LOHAFEX (Indian and German Iron Fertilization Experiment), 2009
Forms of iron used that were used in the above experiments were:

- Ferrous Sulphate (powdered)
- Fe chelate (powdered)
- Iron Sulphide (powdered)
- Haematite dust (fine powder)

2.3.1. Observations made from the experiments:

1) Climatic

<table>
<thead>
<tr>
<th>Observation</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in Dimethyl Sulphide (DMS), Dimethylsulfoniopropionate (DMSP) seen in IronEx II, SOIREE, and EisenEx</td>
<td>Potentially increase cloud cover. This may increase the albedo of the planet and cause cooling (CLAW HYPOTHESIS).</td>
</tr>
<tr>
<td>30 times increase in phytoplankton and 2500 metric tonne of CO₂ removed during IronEx II.</td>
<td></td>
</tr>
</tbody>
</table>
2) **Biological**

<table>
<thead>
<tr>
<th>Observation</th>
<th>Key points &amp; effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diatoms have responded to Fe additions with the greatest increase in biomass in 5 out of 12 experiments.</td>
<td>Diatoms are responsible for 20% of global carbon fixation and 40% of marine primary productivity.</td>
</tr>
<tr>
<td>Fe induced phytoplankton bloom in HNLC surface waters confirmed by high chlorophyll levels.</td>
<td>Increase in marine life</td>
</tr>
<tr>
<td></td>
<td>Carbon Sequestration</td>
</tr>
</tbody>
</table>

2.4. **Industrial production of compounds:**

1) Ferrous Sulphate: -
   (a.) Reacting a source of iron with an aqueous solution of Sulphuric acid in at least a first reaction vessel, to obtain a process liquor comprising ferrous Sulphate and acid Solution
   (b.) Combining the process liquor with concentrated Sulphuric acid in a mixing vessel, causing the solution to self-crystallize, thus forming slurry comprising crystalline ferrous Sulphate monohydrate.

2) Iron Sulphide: -

   FeS can be obtained by the heating of iron and sulphur.
   \[
   \text{Fe} + \text{S} \rightarrow \text{FeS}
   \]

2.5. **How ships can play a role:**

If we are able to cut the cost of the experiment in line with protecting the nature, why shouldn’t we opt for the method of utilising scrap iron from ships?

Iron required for the process can be obtained from the scrap parts of dismantled ships. In this way the cost of the process will be decreased. The scrap parts of ships are always a major concern of the society as it is a major source of pollution. This iron, if not treated properly within a given time, will get rusted and thus will be of no use. The product will be left to pollute the environment.

The iron compounds manufactured by the given process may be dispersed over waters by the functioning/sailing ships.
2.6. Benefits:
The weight of iron required for ocean fertilization for a given region was less than 10 tonnes for each experiment. This cost is still much lesser than the other carbon capture methods and there are serious advantages like the development of marine life in the particular region.

Researches are also done on the addition of other nutrients like Nitrogen and Phosphorous. However, since very small amounts of iron are required by phytoplankton to make organic matter (1 atom for every 50,000 to 200,000 atoms of carbon) compared to the nutrients nitrogen (1 atom for every 16 atoms of carbon) or phosphorus (1 atom for every 106 atoms of carbon), iron fertilization has been seen as the most feasible approach.

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