5

Environmental Impact from Maritime Industry – A Pilot Study on M V AMET MAJESTY- Training cum Cruise Ship

Chief Engineer RAVIKUMAR . K. G *

** Professor, Department of Marine Engineering, AMET University.*

ABSTRACT

*The impact of various Industrial and Human activity on the environmental damage and thereby sustenance / restoration measures, are getting amply recognised and addressed with genuine concern by various stakeholders. This environmental pollution aspect is becoming an alarming issue in the maritime sector too encompassing all the connected supply chain activities apart from sailing. "***A ship lets out around 50 times more sulfur than a lorry per metric tonne of cargo carried.***" Exhaust emissions from ships are considered to be a significant source of air pollution, with 18 to 30 percent of all nitrogen oxide and 9 percent of sulphur oxide pollution.*

It is reported that 3.5 to 4 percent of all climate change emissions are caused by shipping industry. Air pollution from cruise ships is generated by diesel engines that burn bunker oil (high sulphur content fuel oil), producing sulfur dioxide, nitrogen oxide and particulate, in addition to carbon monoxide, carbon dioxide, and hydrocarbons. In fact diesel exhaust has been classified by EPA as a likely human carcinogen. Thus, the environmental impact and sustainability measures on ocean, coastal and air have high relationship with all spheres / domains of maritime activities. (In 2005 MARPOL Annex VI came into force to effectively combat this problem).

Since Cruise Ships comprise only a small fraction of the world shipping fleet, but their emissions may exert significant impacts on a local scale in specific coastal areas that are visited repeatedly. There is little cruise-industry specific data on this issue. Shipboard incinerators also burn large volumes of garbage, plastics, and other waste, producing ash that must be disposed of. As such cruise ships now employ CCTV monitoring on the smoke stacks as well as recorded measuring via opacity meter and are also using clean burning gas turbines for electrical loads and propulsion in sensitive areas. This pilot study has been done using on board data from AMET University's Training Ship "MV AMET Majesty" and a comparison with "Motor Tanker ORANA"

KEY WORDS: Marine Pollution, Energy Efficiency Design Index (EEDI) , Energy Efficiency Operational Indicator (EEOI) , Ship Energy Efficiency Management Plan (SEEMP), Environmental ship indexing (ESI)

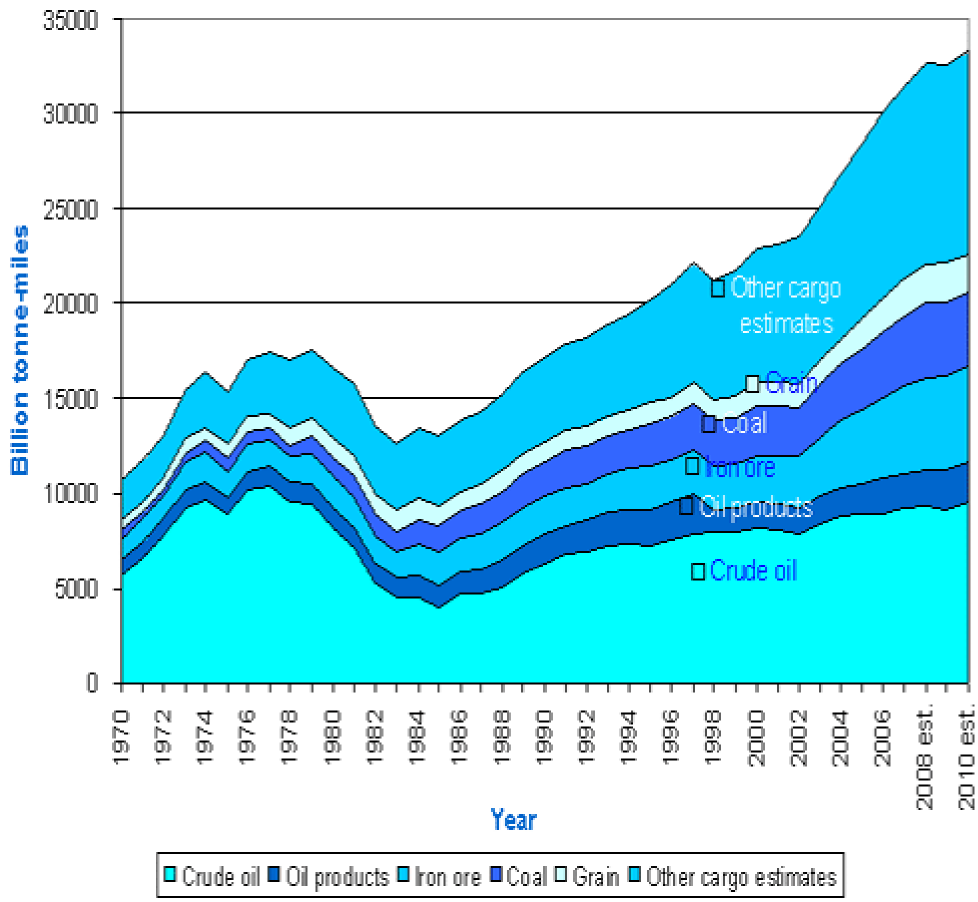
1. NEED FOR THE STUDY

With an increasingly growing genuine concern about the Environmental Impact globally, arising from various pollutants, the contributions from Maritime Industry too needs to be addressed. Air, navigable waters, Territorial or International, coastline and adjoining beaches face the brunt of pollution from the Maritime Activities. Around 90% of world trade is carried by the International shipping industry. Without the Maritime Trade and Shipping, the import and export of goods, on the scale necessary for the modern world, would not have been possible. Seaborne trade continues to expand, bringing benefits for the consumers across the world through competitive freight costs. There are over 50,000 merchant ships trading internationally, transporting every kind and type of cargo. The world fleet is registered in over 150 nations, and manned by more than a million sea-farers of virtually from every nationality. Over the last three decades, activity in the marine shipping sector, as measured in metric ton-kilometers, has grown by an average of 5 percent every year, as in Figure-1. Since polluting emissions from ocean-going vessels have only been moderately con-trolled, this growth has been accompanied thus by a commensurate increase in the sector's contribution to local and global pollution.

The maritime-generated environmental issues are more complicated, since the air above the ocean have no private ownership and the

kind of environmental impacts are very difficult to assess and then to have a solution, hence calls for more International cooperation. International Authorities have through various conventions stipulated stringent measures to be adopted to control and combat this pollution issues for all classes of Vessel's when conducting business in International and Territorial Waters. One among the main conventions is "International Convention for the Prevention of Pollution from Ships, 1973", as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997(MARPOL).

Other conventions relating to the prevention of marine pollution are also in vogue and in practice. A broader look into the conventions and suggestions guide the Maritime Industry to operate the Ships to help maintain a cleaner atmosphere and pollution free navigable waters. Other pollutions from ships seem to be very small, when compared to their emission. Today the need is much pronounced to adapt for arising concern over the Green House Gas (**GHG**) emissions contributing to global climate change. The present day new ships emerging from the docks in fact are checked to comply with these existing conventions. In today's environmentally conscious world there is already much pressure on ship-owners to minimize the impact on the environment due to their operations. However the old ships are yet to be suitably modified to adhere to these conventions.



WORLD SEABORNE TRADE 1969-2010

Figure -1 Source: Fearnley's Review

Albeit, stricter rules being there in place now and more and more countries are agreeing to ratify the same, ironically, the operators of the older ships either delayed or deferred these necessary changes to a later date due to economical constraints and / or partly due to practical implementation issues. Presently list of Amendments and Enforcements' dates are given by the International Maritime Organisation (**IMO**) and effective implementation is checked by the various approved Classification Societies like Lloyds, DNV, ABS, NYK etc. Under these circum-stances, accelerated adoption of cleaner marine fuels and wider deployment of existing pollution control technologies and emission reduction strategies could dramatically improve the environmental friendly performance of the shipping sector.

2. FACTORS CONTRIBUTING TO MARINE POLLUTION

A ship carries oil as fuel for its propulsion and power generation, also different chemicals, oil, ores and other goods hazardous/non hazardous as their main cargo. Marine pollution normally occurs due to various factors such as: Faulty Design, Operational and Accidental, Bal-last Discharge, Deliberate Dumping of Pollutants and Garbage, Emergency Situations and also due to Bad Weather Conditions. However each of the reasons cited above can be effectively controlled to keep marine environmental pollution to the minimum.

A. **Fuel Oil:**
The exhaust from the combustion in diesel engines and Boilers produce waste gases which necessarily contain different gases each harming the atmosphere in some ways. The use of fuel oil produces the sludge- which coupled with accumulated water and other leakage oils used for lubrication purposes is the major pollutant.

Similarly oil tankers do tank cleaning and washings often in the sea. Disposal of such kind of residues by other than approved means pollute the seas'.

B. Oil Spills:
This source of pollution have devastating effects on the environment causing permanent damage to the ecology. Crude oil contains poly-cyclic aromatic hydrocarbons (**PAH**s) which are very difficult to clean up, and last for years in the sediment and ruin the marine environment. Marine species constantly exposed to PAHs can exhibit developmental problems, susceptibility to disease, and abnormal reproductive cycles.

C. Ballast water:
When a large vessel such as a container ship or an oil tanker unloads cargo, seawater is pumped into other compartments in the hull to help her to stabilize and balance. During loading of cargo this ballast water is pumped out from these compartments. The water so obtained from one port (say, one part of the world) contains marine water bodies not congenial in other port and when discharged becomes a transport of harmful organisms. Ballast and bilge discharge from ships can also spread human pathogens and other harmful diseases and toxins potentially causing health issues for humans and marine life alike.

D. Improper chemical disposals:
Improper disposal of Toxic Waste such as (PCB) to heavy metals and Poly-aromatic hydro-carbons (PAHs) are responsible for causing genetic chromosomal aberrations in many marine animals. Tank cleanings from Chemical carriers and certain Hull paints also fall in this category.

E. Garbage disposals:

Garbage originates from all discarded wastes from the ship and includes used and discarded materials like fishing nets, plastics, garbage etc.

E. **Sewage Disposal:**

Sewage is the drainage and other wastes from any form of toilet, urinal or other waste water when mixed with such drainages. Any sew-age discharged from a vessel will be either one of the following either treated or untreated. Raw sewage from cruise ships is similar to standard sewage from the household in the land. It contains bacteria and viruses hazardous to humans, can reduce the oxygen levels in the water, can cloud water preventing light reaching the sea bed (essential for most coral growth) and can introduce harmful levels of nutrients to the environment which could lead to potentially toxic algal blooms.

F. **Ship breaking or ship demolition:**

This is a type of ship disposal involving the breaking up of ships for scrap recycling, with the hulls being discarded in ship graveyards. Ships (particularly older vessels) can contain many substances that are banned or considered dangerous in developed countries. Dangerous vapors and fumes from burning materials can be inhaled, and dusty asbestos-laden areas around such breakdown locations are much common. Aside from the health of the yard workers, in recent years, ship breaking has also become an issue of major environmental concern. Since large quantities of highly toxic materials escape into the environment it causes serious health problems to ship breakers, the local population and wildlife. Environmental campaign groups such as Green-peace have made the issue a high priority for their campaigns.

G. **Exhaust Emissions:**

This alone is considered to be a major source of air pollution from ships. Seagoing vessels are responsible for letting into the atmosphere an estimated 14 percent of nitrogen

from fossil fuels and 16 percent of sulfur from the petroleum product uses. These vessels contribute significantly to global emissions of nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter (PM). Pollutants such as NOx, SOx, and PM have been linked to a variety of adverse public health outcomes, including increased risk of premature death from heart and pulmonary diseases and worsened respiratory disease. Marine emission sources are therefore responsible for a growing share of the public health impacts of exposure to air pollution in many regions. Currently, carbon dioxide (CO2) emissions from the International shipping sector as a whole exceed annual total greenhouse gas emissions from most of the nations listed in the Kyoto protocol as Annex- I countries (Kyoto Protocol 1997).

The present study is limited to Exhaust Emission aspect of pollution.

3. CURRENT SCENARIO:

There have been significant improvements in the engine efficiency and hull design, and the use of ships with larger cargo carrying capacities have led to a reduction in emissions and an increase in fuel efficiency. Eventually atmospheric pollution from newer ships has reduced in the last decade considerably.

However, there is still worldwide concern about atmospheric pollution and global warming and the shipping industry has been playing its part in high level discussions at the International Maritime Organisation (IMO) on reducing emissions from Ships. In terms of CO2 emissions per tonne of cargo transported per kilometer, shipping is regarded as the most efficient form of commercial transport, around 4% of total global CO2 emissions.

For more information refer www.shippingandco2.org

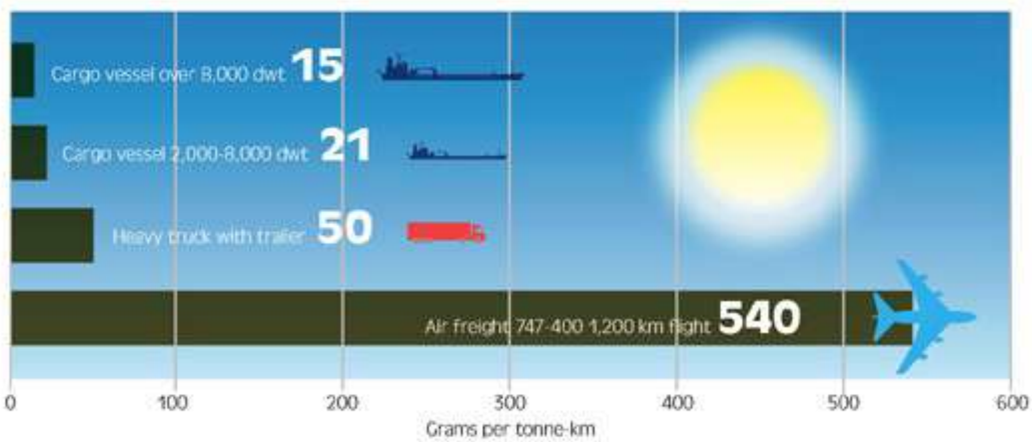


Fig 2 Comparison of CO2 emissions by different transport modes

The Marine Environment Protection Committee, at its fifty-ninth session (13 to 17 July 2009), recognised the need to develop an energy efficiency design index for new ships in order to stimulate innovation and technical development of all elements influencing the energy efficiency of a ship from its design phase and agreed to circulate the Interim Guidelines on the method of calculation of the energy efficiency design index for new ships, as set out in the annex. (IMO T5/1.01 MEPC.1/Circ.681dated 17th August 2009)

To put to use Guidelines provided by IMO and World Port Climate Initiative gives us a way to measure ship's performance with regard to fuel efficiency. The proposed indices are:

1. **Energy Efficiency Design Index** (**EEDI**) - is an interim guideline on the method of calculation of the energy efficiency design index for new ships, developed by the Merchant Environment Protection Committee (MEPC).

2. **Energy Efficiency Operational Indicator** (**EEOI**) – developed by MEPC.

Effective application of this tool establishes a mechanism to achieve the limitation or reduction of greenhouse gas emissions from ships in operation. In its most simple form *the Energy Efficiency Operational Indicator* is defined as the ratio of mass of CO2 (*M*) emitted per unit of transport work: Indicator = *M*CO2 / (transport work)

The data required from the ship will be, *Fuel consumption*, FC (all fuel consumed at sea and in port or for a voyage or period in question), Distance *sailed* means the actual distance sailed in nautical miles (deck log-book data) for the voyage or period in question.

The basic expression for EEOI for a voyage is defined as:

$$\text{EEOI} = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D} \quad \text{Equation 1}$$

where average of the indicator for a period or for a number of voyages is obtained, then Indicator is calculated as:

$$\text{Average EEOI} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{\sum_i (m_{cargo,i} \times D_i)} \quad \text{Equation 2}$$

Where:

j is the fuel type;

i is the voyage number;

FC_{ij} is the mass of consumed fuel j at voyage i;

C_{Fj} is the fuel mass to CO_2 mass conversion factor for fuel j;

m_{cargo} is cargo carried (tonnes) or work done (number of TEU or passengers) or gross tonnes for passenger ships;

D is the distance in nautical miles corresponding to the cargo carried

3. Fuel mass to CO2 mass conversion factors (*CF*) :

CF is a non-dimensional conversion factor between fuel consumption measured in g and CO2 emission also measured in g based on carbon content. The value of *CF* is as follows:

Type of fuel	Reference	Carbon content	C_F (t-CO_2/t-Fuel)
1. Diesel/Gas Oil	ISO 8217 Grades DMX through DMC	0.875	3.206000
2. Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.86	3.151040
3. Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.85	3.114400
4. Liquified Petroleum Gas (LPG)	Propane Butane	0.819 0.827	3.000000 3.030000
5. Liquified Natural Gas (LNG)		0.75	2.750000

Various other required parameters should be obtained and utilised as mentioned in the guidelines for arriving at the EEOI Indicator. For a voyage or period, e.g., a day, data on fuel consumption/cargo carried and distance sailed in a continuous sailing pattern could be collected as shown in the reporting sheet below.

CO_2 Indicator reporting sheet

NAME AND TYPE OF SHIP						
Voyage or day (i)	Fuel consumption (FC) at sea and in port in tonnes				Voyage or time period data	
	Fuel type ( )	Fuel type ( )	Fuel type ( )		Cargo (m) (tonnes or units)	Distance (D) (NM)
1						
2						
3						

NOTE: For voyages with *m*cargo =0, it is still necessary to include the fuel used during this voyage in the summation above the line. \

4. Ship Energy Efficiency Management Plan (**SEEMP**): The purpose of a Ship Energy Efficiency Management Plan (SEEMP) is to establish a mechanism for a company and / or a ship to improve the energy efficiency of a ship's operation. The ship-specific SEEMP is linked to a broader corporate energy management policy for the company that owns, operates or controls the ship; The SEEMP seeks to improve a ship's energy efficiency through four steps: planning, implementation, monitoring, and self-evaluation and improvement. These components play a critical role in the continuous cycle to improve ship energy management.

5. **Environmental ship indexing** (**ESI**): Fifty five of the world's key ports have committed themselves reducing their greenhouse gas emissions (**GHG**) while continuing their role as transportation and economic centers. This commitment is called the World Port Climate Initiative (**WPCI**) (refer www.wpci.nl). One of the missions of WPCI is to initiate actions to reduce GHG emissions and improve air quality in the shipping sector.

One of the projects within WPCI is the development of an Environmental Ship Index (**ESI**). The ESI identifies seagoing ships that go beyond the current standards in reducing air emissions. Up to now, it was not possible to identify these ships in a more general way. The index is intended to be used by ports to promote clean ships, but can also be used by shippers and ship owners as a promotional instrument. (**IAPH, 2009).** The Main Characteristics of the ESI:

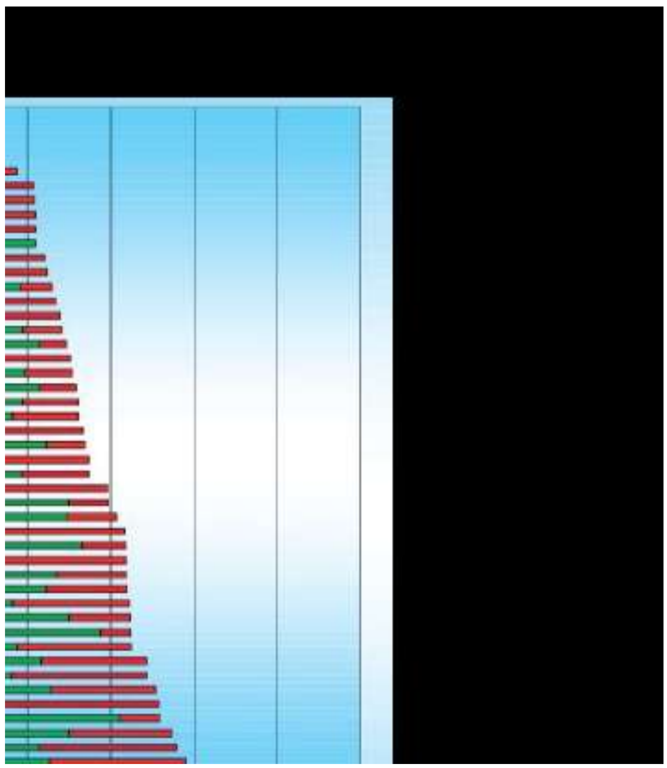
I. It is a voluntary system, helping to improve the environmental performance of maritime shipping.

II. ESI is an instrument to distinguish ships in their environmental performance regarding air quality pollutants and CO2.

III. The ESI gives points for the performance of ships compared to the current international legislation (mainly IMO).

IV. ESI only takes the NOx and SOx emissions directly into account and awards documentation and management of the energy efficiency. PM10 is indirectly included because of its strong relationship to SOx.

V. ESI can be applied to all types of ships and is easy to establish and to obtain for every ship.



It is expected that as from 2011 the ESI will be used by ports to promote clean shipping. The over-all ESI formula is built up of different parts for NOx, SOx and CO2. The weight of the ESI NOx in the overall index is twice the weight of ESI SOx. This reflects the fact that the average environmental damage from NOx3 in ship air emissions is approximately twice the damage from SOx. The overall ESI ranges from 0 for a ship that meets the environmental performance regulations in force to 100 for a ship that emits no SOx and NOx and reports or monitors its energy efficiency. Considering the air pollution aspects for a case study, focus is needed on analysing Emission arising from the Ships. .

The formula for the index is:

$$ESI_{overall} = \frac{1}{3.1}\left(2 * ESI\_NO_x + ESI\_SO_x + RR\_CO_2\right)$$

where:
ESI NOx is the environmental ship index for NOx. ESI SOx is the environmental ship index for SOx. RR_CO2 is the reward for reporting on ship energy efficiency based on the EEOI or a SEEMP.
The ESI NOx and ESI SOx both range from 0 to 100.

ESI NOx

It is calculated with the NOx emissions levels based on the rated power per engine. All Main and Auxiliary Engines must be included.

$$ESI\_NO_x = \frac{100}{\sum_{i=1}^{n} P_i} \times \sum_{i=1}^{n} \frac{(NO_x\ \text{limit\_value}_i - NO_x rating_i) \times P_i}{NO_x\_\text{limit\_value}_i}$$

where: **Pi** is the rated power of engine i. **NOx** rating i is the certificated NOx emissions of engine I in g/kWh. NOx_limit value **i** is the maximum allowable NOx emissions for an engine with the speed of en-gine **i** and **n** number of engines.

ESI SOx

The ESI SOx reflects the reduction in sulphur content of the fuels below the limit values set by IMO and regional authorities. Three types of fuel are distinguished: fuels used at high seas, fuels used in (Sulphur) Emission Control Areas (ECA) and fuels used at Berth.

ESI SOx is defined as:

$$ESI\_SOx = a\% * 30 + b\% * 35 + c\% * 35$$

where**:** a = the relative reduction of the average sulphur content of fuel used on the high seas. b = the relative reduction of the average sulphur content of fuel used in the ECA'S. ` c = the relative reduction of the average sulphur content of fuel used at berth.

RR_CO2

CO2 emissions are not reflected in the index directly. However, the ESI rewards ships that report on energy efficiency with 10 points.

8. Clean Ship Index:

Emphasises the need for clean ships including a variety of parameters in ship operation adopted on board monitoring the emissions to air and sea are acceptable and more efficient. The Clean Shipping Project started 2007 with the ambition to enhance this process from a regional /national perspective. (www.cleanshippingproject.se)

Many other Indices are also developed to monitor the emissions. RightShip has developed an Existing Vessel Design Index (**EVDI™**) and a Greenhouse Gas (**GHG**) Emissions Rating. Similar to the IMO MEPC's EEDI, RightShip's EVDI™ measures a ship's CO2 emissions and can be applied to existing ships. The GHG Emissions Rating is a practical measure derived from the EVDI™ that allows relative comparison of a ship's CO2 emissions to vessels of a similar size and type. Ship types considered here are largely consistent with those used by IMO MEPC.

4. PILOT STUDY:

a. Methodology:

All the relevant data for estimating the Emission from a cruise vessel will be collected and analysed for various Indices. The guideline parameters for assessing the environmental impact because of the Vessel's exhaust gases with the various log books are tabulated. After the scrutiny of the available data and the calculated Indices remedial measures are to be suggested.

b. Particulars of the Cruise Vessel with Voyage details:

Name of the Ship: **MV AMET MAJESTY** – A Training cum Cruise Ship owned by AMET University.

Engine Particulars: Main Engine-SEMT-Pielstick (built 1975) 12 PC2V: 4 X 4400 = 17600KW; 4 X 6000 = 24000BHP Specific Fuel Consumption: 250gm/BHP hr; 335.12gm/kW hr; IFO 180 cst @ 150C Auxiliary Engines Wartsila 824TS: 4 X 975KW = 3900KW: Low Sulphur High Speed Diesel Auxiliary Boiler SUNROD CHSB 25; 2.5 tons/hr; 3 bar.

c. Particulars of **Motor Tanker ORANA** with Voyage details: Engine Particulars: Main Engine-T/C Sulzer 6 RTA 52: 10000 PS Engine Built: 1991; Yard: Japan. SFC =124.8gm/bhp hr; Fuel type: IFO 380 cst @ 150C

Calculating Energy efficiency operational indicator (EEOI), using sample values obtained for Vessel's movement around and the East Coast Chennai and Vishakhapatnam. **MV. AMET Majesty** Voyage data and detail:

Day 1 and 2 are for Vessel moving from Chennai harbour to high seas about 14 nm from shore and back. Day 3 is vessel sailing away from Chennai to Visakhapatnam port. Day 4 and 5 is vessel moving from Visakhapatnam harbour to high seas about 13 nm from shore & back.

MT. Orana Voyage data and detail: Vessel performed one Loaded and Ballast and is taken up for study.

Name of the Vessel	Voyage	Fuel type (IFO - cst)	Fuel type (MGO)	Cargo (m) (tonnes or units)	Distance (D) (NM)	EEOI
MV.AMET MAJESTY	Day1	--	6.2	887.5	28	1.04E-02
MV.AMET MAJESTY	Day2	--	6.2	887.5	28	
MV.AMET MAJESTY	Day3	45.0 (180 cst)	4.1	0	328	

MV.AMET MAJESTY	Day4	--	6.0	860	26	
MV.ORANA Tanker	Voy - 01/B	395.0 (380cst)	1.4	0	5378	5.34E-06
MV.ORANA Tanker	Voy - 01/L	391.8 (380cst)	3.4	4294 6	5369	
MV.AMET MAJESTY	Day5	--	6.0	860	26	

CF = Factor for Heavy Oil 3.1144 and CF = Factor For Diesel Oil 3.206

$$\text{EEOI} = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D} \quad \text{Equation 1}$$

EEOI calculated using the formula for MV. Amet Majesty = 1.04 X 10-2 t CO2 (tonnes * nau miles)

EEOI calculated using the formula for MT. Orana = 5.34 X 10-6 t CO2 (tonnes * nau miles)

Estimating ESI SOx from values obtained from Bunker Delivery Receipts on the above mentioned voyages.

Table 1 MARPOL Annex VI Sulphur Limit in Fuel

Date	**Sulphur Limit in Fuel (%m/m)**	
	High sea	**SOx ECA**
2005	4.5	1.5
2007-10		1
2012	3.5	
2015		0.1
2020a	0.5	

a - alternative date is 2025, to be decided by a review in 2018

Amet Majesty: The Main Engine uses IFO 180 cst with sulphur 3.5% at highseas and Low Sulphur High Flash Point HSD with sulphur % varying from 0.147 to 0.162 used for manoeuvring in - out port and ECA areas. The Auxiliary Engines uses the Low Sulphur High Flash Point HSD for all operations. It is at present very much complying with existing required regulatory requirements.

MT. Orana: The Main Engine uses IFO 380 cst with sulphur 2.3 % at highseas and Low Sulphur Marine Gas Oil with sulphur % varying from 0.45 used for manoeuvring in - out port and ECA areas. The Auxiliary Engines uses the Low Sulphur Marine Gas Oil with sulphur % 0.45

	Values of Sulphur in % at	**Name of the Vessel**	**ESI Sox Value**		
	High sea	ECA	Berth		
Baseline Sul-phur	4.5	1	1	—	—
Actual Sul-phur	3.5	0.17	0.17	M.V. AMET Majesty Cruise Liner	64.3
Actual Sul-phur	2.3	0.45	0.45	M.V. ORANA Tanker	53.2

$$ESI\_SOx = a\% * 30 + b\% * 35 + c\% * 35$$

ANALYSIS and INTERPRETATION

As a pilot study, sample values have been taken from Amet Majesty and the EEOI value has been calculated. The vessel is using Low Sulphur Fuel for its Auxiliary Engines and Main Engines while operating within the port vicinities. To compare the values we need a base. Thus the voyage values of **MT. Orana** was compared with limitations. The IMO MEPC has formulated the EEDI, and an Energy Efficiency Operational Indicator (EEOI), as measures of a ship's CO2 emissions. The EEDI is calculated using characteristics of the ship at build; incorporating parameters that include ship capacity, engine power and fuel consumption, and it cannot be applied at present.

RightShip has developed an Existing Vessel Design Index (EVDI™) and a Greenhouse Gas (GHG) Emissions Rating. Similar to the IMO MEPC's EEDI, RightShip's EVDI™ measures a ship's CO2 emissions, however, unlike the EEDI, the EVDI™ can be applied to existing ships. The GHG Emissions Rating is a practical measure derived from the EVDI™ that allows relative comparison of a ship's CO2 emissions to vessels of a similar size and type. Ship types are largely consistent with those used by IMO MEPC.

Hence a detailed study is planned to be conduced by the author at Ph.D level with datum as specified in the RightShip's EVDI™ for a complete analysis.

CONCLUSION

Depending upon the Age of the vessel, type of the Main and Auxiliary Engines and the fuel used, determine the impact it makes on the Marine Environment. The variety of control measures applied in general are as follows:

1. For NOx reduction, internal engine modifications, water/fuel emulsions, water or water vapour introduced into the combustion process, and SCR;
2. For SO2 reduction, lower sulfur content in fuel, and once water quality issues can be resolved, seawater scrubbing;
3. For PM reduction, SO2 reduction measures, as well as advanced diesel oxidation catalysts and par-ticulate filters.

The Pilot study indicates the operation of the vessel in and around Port areas and on High Seas using a fuel such that the present Emission regulations are strictly adhered to. However this also warrants a detailed study encompassing the full functioning of Ships Machineries such that a Ship Energy Efficiency Management Plan (**SEEMP**) is established. Assessment and conducting of energy audit will ensure that the entire operation is conducted in an efficient manner.

References

IMO Website www.imo.org
IAPH + PORT ENVIRONMENT COMMITTEE (WPCI)
` www.marisec.org/shippingfacts/worldtrade/index.php

www.cleanshippingproject.se