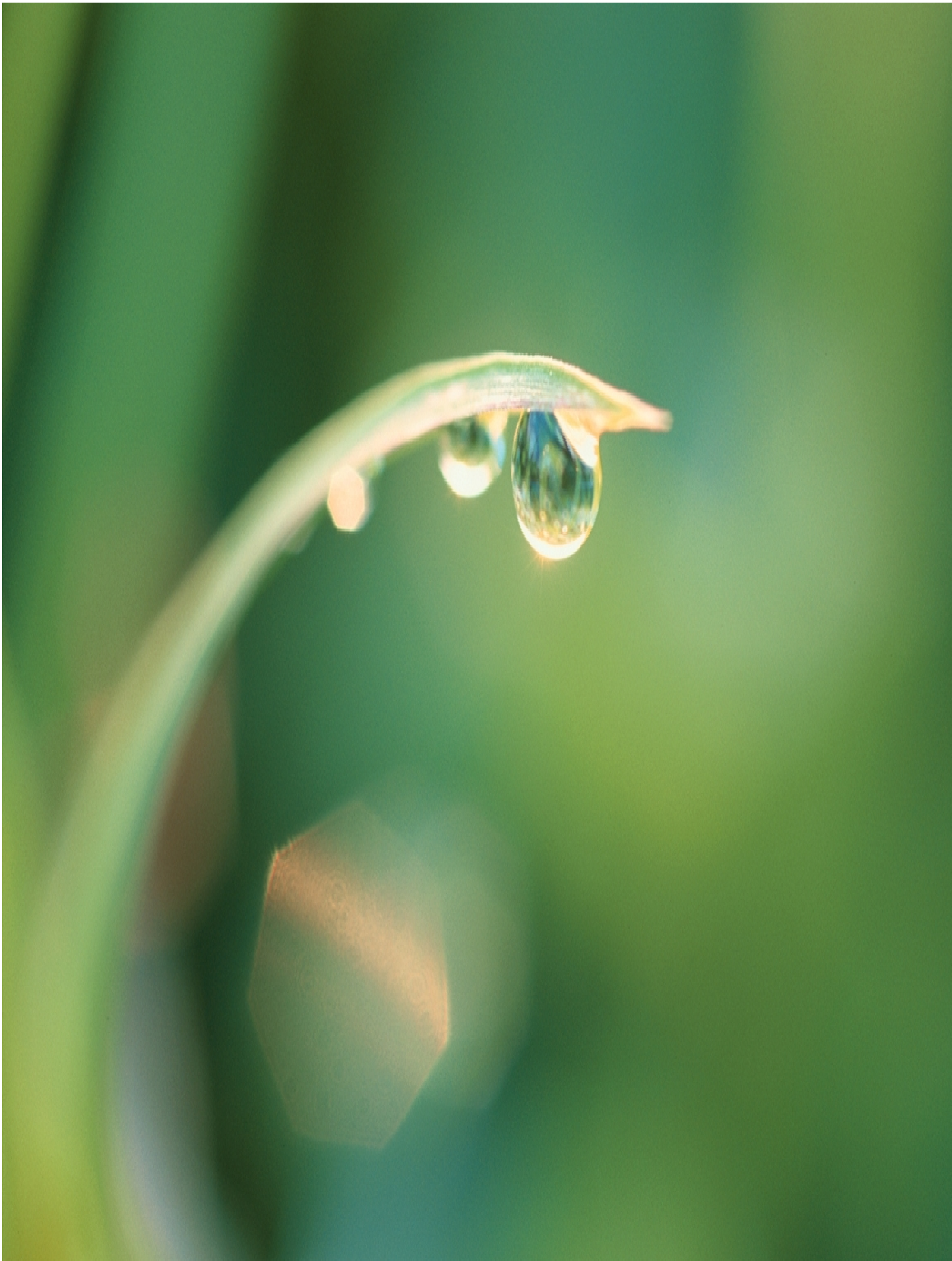

TRANS TECH

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Technical paper on:

"Environmental IMPACTS AND its REMEDIES"

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ABSTRACT

Over the centuries we and fore fathers have enjoyed the abundant beauty of the sea. They were dumping wastes like chemicals, oils and many more hazardous goods in bulk packaged form. As the advancement in marine technology these dumping wastages also became advance. Nowdays the burning topics of the marine pollution is emission of SO_x, NO_x and CO_x from the ships. These are potentially damaging to the environment which (in addition to the protection of life at sea) is why maritime safety is always paramount.

CO_2 (a type of CO_x) emission is considered as one of the greatest threats to the environment. So in the following paper we have expressed our concern about the same.

The atmospheric concentration of the CO_2, the most significant green housegas(GHG),has increased. The increased concentration of green house gases in the atmosphere and the associated warming effects are considered to cause climate change. Till now the effects observed include a decline in mountain glaciers and in snow covers a change in arctic ice coverage and a rise in global average sea level. More frequent extreme weather conditions-such as storms, heat waves, droughts and an increased intensity of tropical cyclones-are also being observed. These factors can-just as much as the financial and economic crises-compromise global security, upset human settlement and induce migration. They can also shift agriculture and industrial production, trade, infrastructure and operations including in costal zones and ports and can affect any field related to shipping route and navigation.

Using low sulphur fuel, scrubber technology, selective catalytic reduction, use of gas engines,water injection etc are the techniques to reduce emission.

INTRODUCTION

Emissions by ships significantly contribute to the total budget of anthropogenic emissions. Shipping produces a wide range of emissions. Key compounds that are emitted are carbon dioxide (CO_2), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOC), sulphur dioxide (SO_2), black carbon (BC) and particulate organic matter (POM). Emissions of NO_x and other ozone precursors from shipping lead to formation of tropospheric ozone (O_3) and perturb the concentrations of hydroxyl radical (OH), and hence the lifetime of methane 7 (CH_4). The dominant component of the aerosol resulting from ship emissions is sulphate (SO_4), which is formed by the oxidation of SO_2; this arises from sulphur in the fuel.Ship emissions are released into the marine boundary layer and change the chemical composition of the atmosphere. Compared to other transport modes, the sulphur content of the fuel burned in marine diesel engines and the total amount of SO_x emissions is high.

Further increase of fuel consumption and emissions is expected in the future related to an increase in economic growth and sea borne trade.

In addition to the impact on tropospheric chemistry, particle emissions from ships also change the physical properties of low clouds. Hence, it is necessary to adopt mitigation measures to combat emissions from ship through available technologies.

Keywords:-

Environmental effect, Major polluting factor, Regulation, Emission-reduction technologies.

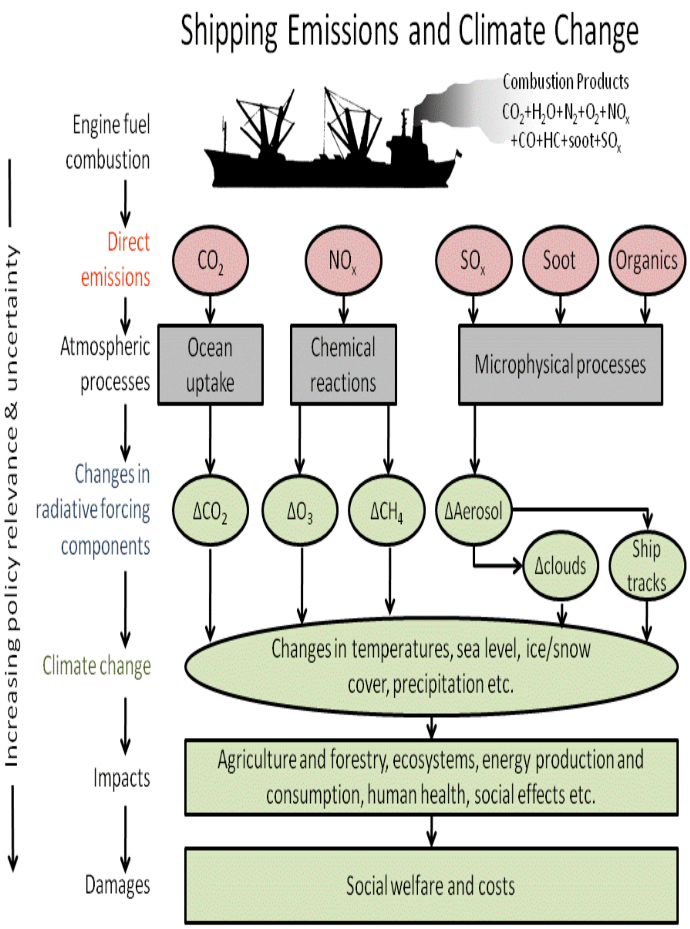
Shipping's environmental credentials:-

Today, the pressure is mounting for every potential polluter, every user of energy and every conspicuous contributor to climate change and global warming to clean up their act and adopt greener practices. Shipping – which transports 90% of global trade – is, statistically, the least environmentally damaging mode of transport, when its productive value is taken into consideration. The vast quantity of grain required to make the world's daily bread, for example, could not be transported any other way than by ship. Moreover, set against land-based industry, shipping is a comparatively minor contributor, overall, to marine pollution from human activities. While there is no doubt that the shipping industry, and IMO, still have more to do in this respect, there is, nevertheless, an impressive track record of continued environmental awareness, concern, action, response and overall success scored by the Organization and the maritime community.

ENVIRONMENTAL EFFECT:-

1) CLIMATE IMPACT:

The overall impacts of (any) emissions on climate are complex, and are summarized conceptually for the shipping sector in figure. Emissions give rise to changes in the abundance of trace species in the atmosphere. Through atmospheric processes, these emission species may undergo atmospheric reactions, alter microphysical processes or be absorbed /removed by various sinks (land and water surfaces) through wet and dry deposition. These changes may then affect the radiative balance of the atmosphere through changes in the abundance of trace species, in atmospheric composition, and in the properties of clouds and aerosols. Such changes in RF may then affect climate in a variety of ways, e.g., global and local mean surface temperature, sea level, changes in precipitation, snow and ice cover, etc. In turn, these physical impacts have societal impacts through their effects on agriculture, forestry, energy production, human health, etc. Ultimately, all of these effects have a social cost, which can be very difficult to quantify. Clearly, as one steps through these impacts, they become more relevant but correspondingly more complex and uncertain in quantitative terms. In this study, we have evaluated climate impacts mostly based on changes in global mean RF and temperature response. It should be noted that this is a simplification, and even changes in local responses that are positive and negative and appear to cancel each other out (e.g., RF responses) may impact climate, in spite of a first-order indicator of such a metric as global mean RF having a small or zero response.



2)IMPACT ON HUMAN HEALTH

At local and regional scales, ocean-going ships impact human health through the formation and transport of ground-level ozone and emissions of sulphur and particulate matter (Corbett *et al.*, 2007). In many harbour cities, ship emissions are a dominant source of urban pollution. Furthermore, emissions of NOx, CO, VOC, particles and sulphur (and their derivative species) from ships may be transported in the atmosphere over several hundred kilometres, and can contribute to air-quality problems further inland, even if they are emitted at sea. This pathway is especially relevant to the deposition of sulphur and nitrogen compounds, which cause acidification/ eutrophication of natural ecosystems and freshwater bodies and threaten biodiversity through excessive nitrogen inputs (Eyring *et al.*, 2007b; 2009). For this reason, control of NOx, SO_2 and particle emissions will have beneficial impacts on air quality, acidification and eutrophication.

Corbett *et al.* (2007) demonstrated that emissions of PM from ocean going ships could cause approximately 60,000 premature mortalities annually from cardiopulmonary disease and lung cancer. This value is expected to increase by 40% by 2012 in their scenarios, which do not
include the new amendments to the regulations of MARPOL Annex VI, to reduce harmful emissions from ships that were adopted by the Marine Environment Protection Committee (MEPC) of IMO in October 2008.

MAJOR POLLUTING FACTORS:-

Background:

The type of fuel used plays a major part in determining the composition of the emissions, an important factor that determines the amount of NO_x, is engine speed (the real factor is residence time). In way of comparison, Table shown below demonstrates typical emissions values for low and medium speed engines.

Indicative emission comparison between low and medium speed diesels engines.

Pollutant

NOx

CO

HC

CO_2

SO_2

Medium Speed Engines (g/kWh)

12.0

1.6

0.5

600

3.6x%S

where S = sulpher content (%m/m)

Low Speed Engines (g/kWh)

17

1.6

0.5

600

3.6x%S

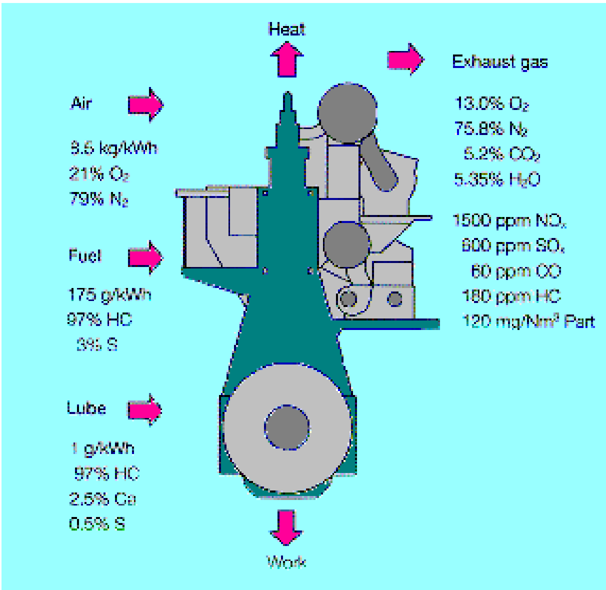


Figure : - Typical emissions from low-speed diesel engine

Each of these emissions will be discussed in turn in the following paragraphs and are summarised in Table.

1)Sulphur Oxides:

The formation of Sulphur Oxides (SO_x) in exhaust gases is caused by the oxidation of the sulphur in the fuel into SO_2 and SO_3 during the combustion process. In the atmosphere, SOx combines with moisture to form H_2SO_4, which then falls as acid rain, and has been linked to environmental damage. The amount of SOx formed is a function of the sulphur content of the fuel used and therefore the only effective method of reducing SO_x is by reducing the sulphur content of the fuel. Unfortunately, low-sulphur fuels are more expensive to purchas. And there is a practical lower sulphur limit desired as desulphurisation of fuel lowers the lubricity of the fuel which can lead to increase wear on fuel pumps and injectors.

The regulation of SOx is predominately a regional issue. However, international pressure is growing for the oil producers to reduce the sulphur content of all fuels in order to control this problem at the source. The current EU Directive, which applies to all gas oil sold on land in the EU, is that the % sulphur content of fuels must remain below 0.2% with the aim of reducing this limit to 0.1% . Special Areas have been set up, such as the Baltic, where the use of low sulphur fuels will be mandatory when Annex VI is ratified and will be limited to 1.5%.

2) Carbon Dioxide:

CO_2 is one of the basic products of combustion and although diesels are one of the most efficient engines for the combustion of fossil fuels, the only way to reduce CO_2 is to either reduce the amount of fuel burned or by increasing thermal efficiency.CO_2 is not toxic however, has been linked to the 'greenhouse effect' and global warming.

Alternative low carbon to hydrogen ratio fuels are already or will soon be used onboard ships, however, it is only a viable solution, if the ship sails with cargoes containing these fuels (i.e. LNG carriers) or cargoes where parts of the cargo evaporates in the form of volatile organic compounds (VOC) as, for instance, on shuttle tankers and crude oil carriers. The VOC gasses can be gathered and used as fuel in VOC diesel engines.

3)Carbon Monoxide:

CO is formed due to the incomplete combustion of organic material where the oxidation process does not have enough time or reactant concentration to occur completely.

In diesel engines, the formation of CO is determined by the air/fuel mixture in the combustion chamber and as diesels have a consistently high air to fuel ratio, formation of this toxic gas is minimal. Nevertheless, insufficient combustion can occur if the fuel droplets in a diesel engine are too large or if insufficient turbulence or swirl is created in the combustion chamber. This will also be accompanied by a large increase in particulates (i.e. black smoke).

4)Hydrocarbons:

The emission of unburned hydrocarbons (HC) generally results from fuel, which is unburned as a result of insufficient temperature or air supply. This often occurs near the cylinder wall (wall quenching) where the temperature of the air/fuel mixture is significantly less than in the centre of the cylinder. Bulk quenching can also occur as a result of insufficient pressure or temperature within the cylinder itself. Still further, HC production may also be a result of poorly designed fuel injection systems, injector needle bounce, excessive nozzle cavity volumes or fuel jets reaching a quench layer. Lubricating oil vapours also contribute to hydrocarbon emissions.

HC reduction, for the most part, can be achieved by good engine design; however further reduction would most likely only be possible using secondary oxidation catalysts.

5)Smoke/Particulates:

The composition and properties of diesel particulates varies greatly and is therefore difficult to define. Furthermore, there is not a quantitative relationship between the smoke opacity and the particulate emission. Particle emissions from diesel engines can originate from:

a.agglomeration of very small particles of partly burned fuel (HC);

b.partly burned lub oil (HC);

c.ash content of fuel oil and cylinder lub oil; or

d.sulphates and water.

The most effect method of reducing particulate emissions is to use lighter distillate fuels, however this leads to added expense. Additional reductions in particulate emissions can be achieved by increasing the fuel injection pressure to ensure that optimum air-fuel mixing is achieved, however, as fuel injection pressure increases, the reliability of the equipment decreases. Much research has also been conducted on cyclone separators, which are effective for particle sizes greater than 0.5μm while electrostatic precipitators are more effective, capable of reduction emissions by up to 99% (in terms of g/kWh).

6) Nitrogen Oxides:

While SOx is predominately a regional issue, NOx is a global issue and the new MARPOL regulations will have a significant impact for ship owners and ship builders.

NOx is formed during the combustion process within the burning fuel sprays and is deemed one of the most harmful to the environment and contributes to acidification, formation of ozone, nutrient enrichment and to smog formation, and has become a considerable problem in most major cities world-wide.

The amount of NOx (ppm) produced is a function the maximum temperature in the cylinder, oxygen concentrations, and residence time. NO is completely converted to NO_2 in the atmosphere within a few hours and being soluble is washed out by rain, which increases the acidity level of the soil.

The best way to reduce NOx generation is to reduce peak cylinder temperatures and there are a number of ways that this can be done. Without additional design changes, most of the methods cause a certain loss in engine efficiency which increases the engines SFC.

The following table provides a summary for the pollutants discussed above.

Emission

Legislated by IMO

Source

Sox

√

Function of fuel oil sulphur content

CO_2

X

Function of combustion

CO

X

Function of the air excess ratio, combustion temperature and air/fuel mixture.

HC

X

Very engine dependant but a function of the amount of fuel and lub oil left unburned during combustion.

Smoke/Particulates

X

Originates from unburned fuel, ash content in fuel and lub oil.

NOx

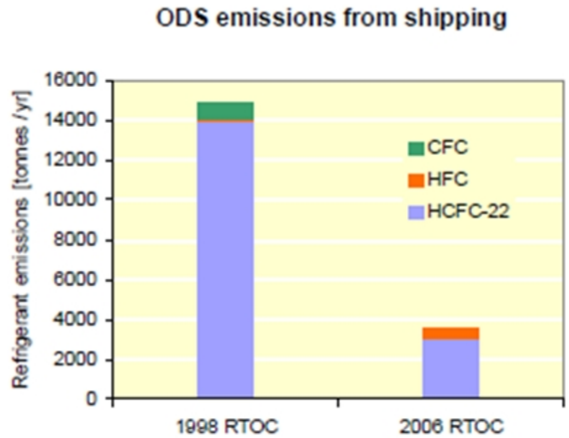
√

Function of peak combustion temperatures, oxygen content and residence time.

Reductions in emissions achieved by implementation of MARPOL Annex VI:-

Regulation 12 – Ozone-depleting substances

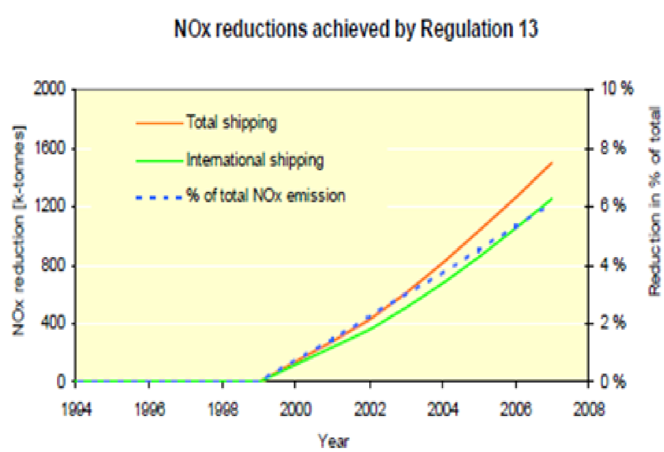
Regulation 12 of MARPOL Annex VI prohibits deliberate emissions of ozone-depleting substances. Regulation 12 also prohibits new installations that use ozone-depleting substances, except that HCFCs may be used until 1 January 2020.



Estimated emissions of ozone-depleting lsubstances

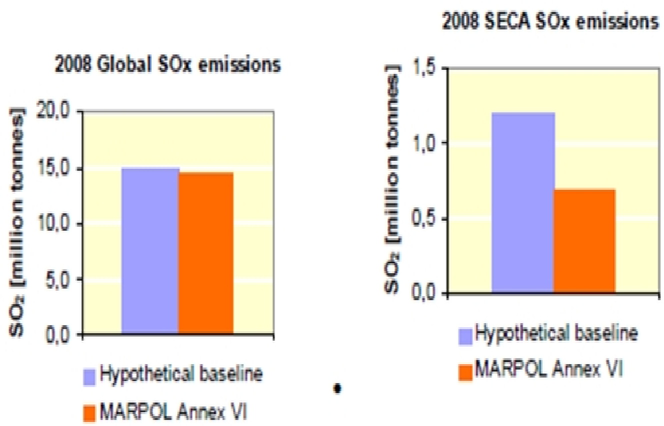
Regulation 13 – Nitrogen oxides (NOx)

Emissions of NOx are addressed in regulation 13 of Annex VI. The original Tier I limit on NOx emissions applies to engines built on or after 1 January 2000. In line with interim guidelines communicated through MEPC/Circ.344 [4], engine builders adhered to the regulation prior to its enforcement.



Regulation 14 – SOx

Emissions of SO_x are addressed in regulation 14 of Annex VI, which caps sulphur emissions globally at 4.50%, and less in SO_x Emission Control Areas (SECAs). In a SECA, the sulphur content of fuel oil used on board ships must not exceed 1.50% by mass. As an alternative, ships may use an exhaust gas scrubbing system. However, this is only done currently in the form of prototype testing on a very limited number of ships.



Reduction for emission of Sox estimated for 2008

Regulation 15 – Volatile Organic Compounds (VOCs)

Emissions of Volatile Organic Compounds (VOCs) are addressed in regulation 15 of MARPOL Annex VI. This regulation deals with how ports and terminals that are under the jurisdiction of parties to the Annex should regulate emissions of VOCs from tanker loading. In particular, where such regulations are employed, parties to Annex VI are to communicate such regulation of activity to IMO. By the end 2008 no party had communicated the existence of such regulation to IMO [9], although several plants for the recovery of VOCs are in operation in various parts of the world, including the USA, Europe and Japan [10].

Emission-reduction technologies:-

Considering the list of pollutants in the scope of this report, emission-reduction technologies are mainly relevant to pollutants within exhaust gases, i.e. NO_x, SO_x, PM, CH_4, NMVOC. Technological options for reducing these emissions are discussed here.

1) Emission-reduction options for NOx:

1) fuel modification, e.g., water emulsion;
2) modification of the charge air,e.g., humidification and exhaust gas recirculation (EGR);
3) modification of the combustion process, e.g., miller timing; and
4) treatment of the exhaust gas, e.g., selective catalytic reduction (SCR).

Tier II NO_x limits, i.e. 15-20% reduction from the current levels, can be achieved with modifications of the internal-combustion process. At present, reduction of emissions of NO_x to Tier III limits (~80% reduction from Tier I) can only be achieved by selective catalytic reduction (SCR) post-treatment or by using LNG and lean premixed combustion. These technologies are proven for four-stroke engines; however, experience with large two-stroke engines is limited.

By using SCR and LNG technology, it is possible to achieve reductions of emissions even beyond Tier III limits on some load points. However, achieving further reductions at low load is problematic with SCR, principally because the temperature of exhaust gases from marine engines are not sufficiently high for effective operation of the catalyst. Achieving reduction of emissions to a very low level consistently, for extended time periods, may prove problematic with a catalyst, due to its possible deactivation. Technology for reduction of NO_x emissions at low load in marine engines is presently being forced by IMO through the modified Tier III test-cycle requirements in the revised NO_x Technical Code.

2)Emission-reduction options for SOx:-

Emissions of SO_x originate in sulphur that is chemically bound to the fuel hydrocarbon.
When the fuel is burned, the sulphur is oxidized to SO_x (mainly SO_2). In order to reduce So_x emissions, it is necessary to use a fuel with lower sulphur content or to remove the SO_x that is formed in the combustion process.

The revised MARPOL ensures that significant reductions of SO_x emissions will be achieved through limitations on the sulphur content of fuel. As an alternative to using low-sulphur fuels, an exhaust-gas scrubbing system can be employed to reduce the level of sulphur dioxide (SO_2). Scrubbing to remove SO_x reduces the temperature of exhaust gas. On the other hand,SCR technology requires high temperatures of exhaust gas and at the same time creates low sulphur and PM content in the exhaust gas. Combining SCR with scrubbing to remove SO_x is thus not considered feasible.

3) Emission-reduction options for PM:-

Unlike other emissions, which are chemically defined, particulate matter (PM) is defined in international standards (ISO 8178) as the mass that is collected on a filter under specified conditions. However, the mass of PM does not define the chemical composition and the size distribution of the PM; these are important to health and in causing environmental effects.
The extent of generation of Particulate Organic Matter (POM) is related to the consumption of engine lubricating oil, which may potentially be reduced. Changes in the base stocks and the additives of lube oil may also reduce PM mass.

Some emissions of PM from high-sulphur fuels can be reduced by scrubbing with seawater. Claims for the potential reduction of PM levels range from 90% to 20%, depending on source .With low-sulphur fuels, emissions of PM can be further reduced by optimizing combustion to achieve increased oxidation of soot and of PM, minimizing consumption of lube oil and minimizing the use of additives in lube oil. The burning of fuel–water emulsions can also reduce emissions of PM to a certain extent.

4) Emission-reduction options for CH_4 and NMVOC:

Emissions of CH_4 from gas engines are due to unburned methane arising from the process of premixed combustion. The level of CH_4 emissions depends on the layout of the combustion chamber. By careful design to avoid crevices, emissions can be significantly reduced. However,
there will be a remaining level of CH_4 emissions. This CH_4 can be oxidized by using a catalyst, though this is not as simple as reducing the levels of

NMVOC, and this is an area for research and development

Assessment of potential reduction of emissions:-

1) Potential for reduction of CO_2 emissions:

The potential for saving energy by combining these options is very significant.
On the other hand, costs, lack of incentives and other barriers prevent many of them from being adopted.
Therefore, when making an assessment of the potential saving, we also make implicit assumptions regarding the degree of compromise, effort and extra costs that would be required.
An assessment of energy-saving potentials, using known technology and practices, is shown in table below.

DESIGN (New ships)	Saving (%) of CO_2/tonne-mile	Combined	Combined
Concept, speed & capability	2–50⁺	10–50%⁺	25–75%⁺
Hull and superstructure	2–20		
Power and propulsion systems	5–15		
Low-carbon fuels	5–15*		
Renewable energy	1–10		
Exhaust gas CO_2 reduction	0		
OPERATION (All ships)			
Fleet management, logistics & incentives	5–50⁺	10–50%⁺	
Voyage optimization	1–10		
Energy management	1–10		

⁺ Reductions at this level would require reductions of speed.
* CO_2 equivalent based on the use of LNG.

2)Potential for reduction of other relevant substances:

(NO_x, SO_x, PM, CO and NMVOC) The reductions in emissions that are mandated or expected from the revised Annex VI are shown in table

Maximum reductions in emissions in the revised Annex VI

	Global	ECA
NO_x (g/kW·h)	15–20%	80%
SO_x* (g/kW·h)	80%	96%
PM (mass) ⁺(g/kW·h)	73%	83%

* Reduction relative to 2.7% sulphur content in fuel.
⁺ Expected reduction of PM from fuel change.

Comparison of SOx, NOx & PM emissions for different technologies:-

Technology /solution	Sox	Nox	PM	Comments
LSFO (<1.5%S)	G	R	R	Primary abatement approach considered by the currentinternational and regional legislation.The availability and price of low sulphur fuel is a sourceof much debate and discussion in both the shipping and oil industries ahead of the implementation of legislation.
Additive Treatment system	G	G	G	Additives cannot remove sulphur in fuel, but they canconvert it to less harmful forms

Hi Efficiency scrubbing	G	G	G	Exhaust gases can be treated to remove sulphur before the gasses are emitted. The basic chemical process is generally to mix the gases with a compound containing calcium, so the SOx is converted to Calcium Sulphate.
Selective catalytic reduction	R	G	R	SCR uses Urea and a catalyst to reduce NO into N_2&H_2O. It requires exhaust temperatures only attained at least half the speed to work efficiently hence the NOx reduction near land during pilotage and manoeuvring when it is most needed is least effective .
Humid air motor	R	G	G	They work by putting water vapour into the inlet air stream, and are effective at reducing NOx. This requires heat input. Under varying loads, it is also hard to control the humidity adequately.

G – Good, R – Room for Improvement

Conclusions:-

The following conclusions were drawn:

1) Increases in well-mixed greenhouse-gases, such as carbon dioxide, lead to positive radiative forcing and to long-lasting global warming;

2) The RF from shipping-generated CO_2 for 2007 was calculated to be 49 mW m−2.

The IPCC Fourth Assessment Report estimated that the total RF from CO_2 (all sources) was 1.66 W m−2 (for 2005), so that shipping contributed approximately 2.8% to the total anthropogenic CO_2 RF in 2005;

While the control of NOx, SO_2 and particle emissions from ships will have beneficial impacts on air quality, on acidification and on eutrophication, reductions of CO_2 emissions from all sources, including ships and other freight modes, are required to reduce global warming. Moreover, a shift to cleaner combustion and cleaner fuels may be enhanced by a shift to technologies that result in the lowering of the amount of CO_2 that is released from each unit of fuel that is used;

And climate stabilization will require significant reductions in future global emissions of CO_2. The emissions from shipping for 2050 that have been developed for thiswork – which are based on SRES non-climate-intervention policy assumptions –constitute 12 to 18% of the WRE 450 scenario, which corresponds to the total global CO_2 emissions permissible in 2050 if the increase in global average temperature is to be limited to 2°C with a probability greater than 50%.

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