Environmental impact and sustainability

Introduction

Emissions from shipping contribute significantly to the concentrations of harmful air pollutants in Europe. There are, still, technical methods which these pollutants could be reduced for 80-90 per cent. These methods are cost-effective compared with land-based sources. Such reductions are needed for protecting health and the environment, and for shipping to develop into a more sustainable kind of transport.

Air emissions have been a major issue for many years between political and shipping groups. More recently, though, the political climate has toughened with the subject being raised from a matter of local pollution to one of ‘ global warming’.

Exhaust emissions from land transport and electricity generation are already heavily regulated within very low limits. Shipping has not yet been greatly affected and the emissions are growing with the increasing sea-borne trade. Shipping consumes about five per cent of global oil consumption which leads to global NOx emissions of about 12. 57 million tonnes / year, and about 10. 54 million tonnes / year global SOx emissions.

Obviously, stricter air pollution control regulations will come for shipping. Yet it is not known which emissions types will be regulated, to what level and when. World shipping has been reported as generating some 438 million tonnes / year of CO2 which is equivalent to about 1. 8 per cent of global CO2 emissions.

Increasing emissions

The emissions of air pollutants from ships engaged in international trade in the seas surrounding Europe – Baltic, North Sea, north-eastern part of the Atlantic, Mediterranean, and the Black Sea – were estimated to have been 2. 6 million tons of sulphur dioxide and 3. 6 million tons of nitrogen oxides (NOx) a year, in 2000.

While pollutant emissions from land-based sources are gradually coming down, those from shipping show a constant increase. Even after the application of MARPOL Annex VI, which sets limits on the sulphur content of marine fuels for the Baltic Sea, the North Sea and the English Channel, emissions of SO2 from international shipping are expected to increase more than 42 per cent by 2020, and those of NOx by two thirds. In both cases, by 2020, the emissions from international shipping around Europe will have exceeded the total from all land-based sources in the 27 member states combined.

It has been estimated that about 90 per cent of the total SO2 and NOx emissions from ships in the North Sea, including the English Channel, originates from a zone of approximately 50 nautical miles (about 90 kilometres) from the coast line.

International shipping within a distance of 100 nautical miles from the coast was estimated to be a source of 97 per cent of the total in the North Sea.

Air quality & health, acidification, eutrophication

Particles

SO2 and NOx can become converted into sulphate and nitrate particles, which are very small and among the most frequent of airborne particles. Exposure to particulate matter (PM) is associated with increased mortality (especially from cardio-vascular and cardio-pulmonary diseases) and sickness. According to the European Environment Agency, up to 45 per cent of Europe's urban population are exposed to PM10 levels (particles of 10 micrometres or less) exceeding the forthcoming EU standards (EEA, 2004). It has been estimated that exposure to particulate matter in outdoor air leads to about 100, 000 deaths annually in Europe , that the effect of PM on life expectancy may be in the order of one to two years. Ship emissions are estimated to contribute between twenty and thirty per cent to the air concentrations of secondary inorganic particles in most coastal areas.

Ground-level ozone

Nitrogen oxides contribute also to the formation of ground-level ozone, which damages vegetation as well as human health.

In the second half of the 1990's, almost all of Europe's urban population were exposed to ozone concentrations above the limit value for the protection of human health. It has been estimated that about 75 per cent of the urban population in southern Europe, and 40 per cent in the northern part, lived in cities where the ozone levels exceeded the EU target value of 120 micrograms per cubic metre (mg/m3) for more than 20 days.

Shipping emissions contribute remarkably to the formation of ground-level ozone, especially in the Mediterranean region, where increased concentrations resulting from ships' NOx emissions amount to 16-20 mg/m3.

The high concentrations of ozone in the Mediterranean region do not only affect human health and crop harvests, but also pose a threat to the region's important tourist industry.

Acidification

In 2000, the depositions of sulphur and nitrogen exceeded the critical loads for acidic substances on more than 260, 000 square kilometres (about 20 per cent) of sensitive forest ecosystems in the EU's member states.

Emissions from ship traffic contribute to exceed of critical loads of acidity by more than 50 per cent in most of the coastal areas along the English Channel and the North Sea, in the Baltic Sea along the coast of Germany and Poland, and also in large parts of southern Sweden and Finland. Also, there are a large number of grid cells in northern Europe where ship emissions are responsible for more than 90 per cent of exceed critical loads for acidity.

Eutrophication

Nitrogen oxides lead to eutrophication, which affects biodiversity both on land and in coastal waters.

In 2000, the depositions of nitrogen exceeded the critical loads for eutrophication on 800, 000 square kilometres (about 60 per cent) of sensitive terrestrial ecosystems in EU.

Also, there are a large number of areas in northern Europe where ship emissions are responsible for more than 90 per cent of exceed critical loads. In the Mediterranean, ship's emissions contribute more than 50 per cent of exceed critical loads in parts of Greece, Italy, and Spain.

Although most of the SO2 and NOx emitted from ships operating in international trade get deposited over the sea, shipping is the largest single source of acidifying and eutrophying result over many countries in Europe.

Corrosion

Air pollutants, such as sulphur dioxide, nitrogen oxides, and ozone, accelerate the rate of weakening of a large number of various materials. Buildings and monuments made of limestone and some kinds of sandstone are especially sensitive to corrosion from acidic substances. Also metals become corroded more quickly in an acid environment.

Ozone is known to speed up the disintegration of textile materials, leather and rubber.

Climate change

Emissions from ships also contribute to global warming. An estimate of the change in net irradiance at the atmospheric boundary between the troposphere and the stratosphere (radiative forcing) due to CO2 emissions from ships indicates that ships may account for 1. 8 per cent of the global. Additionally, according to a study made for the IMO Marine Environment Protection Committee, the radiative forcing resulting from increased levels of ground-level ozone due to NOx from international shipping are highly likely to produce positive forcing effects that will contribute to global warming and that could be in the same range as (or larger than) direct forcing from CO2 (Henningsen, 2000).

Modes of Transport and Emissions

Truck versus ship emissions

Comparison of the environmental performance of different modes of transport is difficult, but by tightening down the comparison to a few air pollutants, some conclusions can be made. In terms of today's average vehicles and fuel, a ship will emit out 30-50 times more sulphur per ton-kilometre than a truck. When diesel becomes even cleaner in 2005, the difference increased to 150-300 times.

Trucks advantage over ships even if ships are run on oil with a sulphur content of 1 per cent. This comes from the fact that the highest allowable sulphur content of diesel oil for road traffic has been gradually brought down by regulation. As from 2000 it was lowered in the EU to 350 ppm (parts per million), and in 2005 it is further reduced to 50 ppm. A further reduction to below 10 ppm is anticipated by 2010 – such fuels are already being placed on the market. On the other hand, the average sulphur content of marine heavy fuel oil used in European waters is about 2. 7 per cent, i. e. 27, 000 ppm.

Regarding to nitrogen oxides, ships release about twice as much NOx per ton-kilometre as the latest truck models today, and the difference is set to increase (again see Table 3). In 2005, the emission standards for trucks in the EU were cut from the present 5. 0 to 3. 5 g/kWh, and in 2010 to 2. 0 g/kWh.

According to a recent report, the burning of marine heavy fuel oil gives rise to high emissions of polycyclic aromatic hydrocarbons (PAH). Because of its high content of polycyclic aromatics, this type of fuel is classified as cancer-

causing and harmful to the environment. If we compare to a heavy diesel-driven truck, the PAH emissions from a ship using marine heavy fuel oil are about 30 times higher per energy unit. i. e. if the energy output of a ship's engine is 40 times of a truck engine, the PAH-emissions from a fairly large vessel entering a port will correspond to those from about 1200 heavy trucks.

Energy Plants vs. Ships

Sulphur emissions from land-based stationary sources are in the EU regulated by several instructions, directive 1999/32 on the sulphur content of liquid fuels, directive 2001/80 on the limitation of emissions from large combustion plants, and directive 1996/61 concerning integrated pollution prevention and control.

According to directive 1999/32, the maximum allowed emissions from all oil-fired plants must not exceed the equivalent of using heavy fuel oil with a sulphur content of 1 per cent. For gas oils, including for marine use, the limit are set stricter, at a maximum of 0. 2 per cent, and it is further reduced to 0. 1 per cent as from January 2009 (Figure 3). Any new large combustion plants (i. e. with a thermal capacity of more than 50 megawatts) built after 2003, according to directive 2001/80, keep their SO2-emissions below levels equivalent to maximum sulphur contents in fuel oil of between 0. 1 and 0. 5 per cent. The bigger the plant, the stricter the emission limit value will apply.

International action so far

Although some countries, such as Sweden and Norway, have taken steps to tackle the problem of ships' emissions independently, on the whole, little has been done about it.

Shipping is an international business, it would be logical to try and bring global agreement for control of its emissions, and an attempt has been made in the Marine Environment Protection Committee of the UN International Maritime Organization (IMO). After years of negotiation, agreement was reached in

1997 on an air-pollution annex to the MARPOL 73/78 Convention. But this agreement was so fragile that it was obvious it would have little effect. Annex VI establishes a global sulphur cap of 4. 5 per cent for bunker fuel, and it designates two so-called sulphur emission control areas (the Baltic Sea and the North Sea), where fuel used by ships must be below 1. 5 per cent. It also suggests emission standards for NOx for diesel engines with a power output greater than 130 kilowatts, but these standards are so weak that virtually all new engines are already in compliance.

Following its confirmation by 15 countries representing the 50 per cent of the gross tonnage of the world’s merchant fleet, Annex VI came into force in May 2005.

In practise this will mean that the 1. 5-per-cent sulphur limit apply to all ships in the Baltic Sea as in May 2006, while the corresponding requirement for the North

Sea wasdelayed until 2007. 2008 Amendments (Tier II/III)â€” Annex VI amendments adopted in October 2008 introduced (1) new fuel quality requirements beginning from July 2010, (2) Tier II and III NOx emission standards for new engines, and (3) Tier I NOx requirements for existing pre-2000 engines. The revised Annex VI enters into force on 1 July 2010. By

October 2008, Annex VI was ratified by 53 countries (including the Unites States), representing 81. 88% of tonnage. The voting rules of the MARPOL convention, as well as experience to date, make it unlikely that possible further moves by the IMO will result in any significant emission reductions in the near future.

Protocols for reducing emissions under the Convention on Long-Range Trans boundary Air Pollution (LRTAP) do not cover those from international shipping. Also, the emissions of greenhouse gases from international shipping are not covered by the Framework Convention on Climate Change or its Kyoto protocol.

Although it has long been held within the European Union that shipping is a matter for the IMO, the Commission has recently been investigating the economic, legal, environmental, and practical implications of coordinated EU action for reducing the emissions of air pollutants from ships. This initiative has been encouraged among others because the EU directive on national emission ceilings required the Commission to present a program of action for reducing emissions from international maritime traffic before the end of 2002.

CO2 emission control methods

Water injection

Water injection is a method for cooling the combustion chambers of engines by adding water to the entering fuel-air mixture, allowing for greater compression ratios and largely eliminating the problem of engine knocking. This effectively increases the octane rating of the fuel, and performance gains can be obtained when used in combination with a supercharger or

turbocharger, altered spark ignition timing, and other modifications. Many water injection systems use a mixture of water and alcohol (usually 50/50), partly because the alcohol is flammable, while water is not; in addition, the alcohol serves as antifreeze for the water.

The initial injection of water cools the fuel-air mixture fairly, which allows more mixture to enter the cylinder. Greater effect comes later during combustion when the water takes in, significant amounts of heat energy as it converts from liquid to gas, increasing piston pressure and reducing the peak temperature with its resulting NOx formation as well as the amount of energy absorbed into the cylinder walls.

The duration of combustion is said to be longer. An interesting side effect that has been reported is that water injection effectively “ steam cleans” the engine interior, resulting in less carbon excess build-up. Hot carbon deposits are cause of knocking.

Eco Silencer

The Eco Silencer design has undergone several years of testing and shipboard trials that have proven the system’s ability to reduce SOx exhaust emissions and remove soot particulate as well as reduce exhaust noise. Depending on the vessel’s engine configuration, the Eco Silencer has the ability to reduce SO2 exhaust emissions by up to 90 % – with a minimum performance guarantee that will allow burning the maximum 4. 5% sulphur fuel and still surpassing the regulated reduction to 1. 5% sulphur fuel. The acidic gasses, and particulate removed from the exhaust gas are pass

through a water treatment system is designed to filter wastes on a continuous basis, and to provide outlet water that is environmentally safe.

Reducing emissions of NOx

There are various methods for reducing NOx emissions, differing somewhat in cost and effectiveness.

Selective Catalytic Reduction, SCR

It can reduce the emissions of NOx by more than 90 per cent, but may require the use of low-sulphur fuel. When retrofitted it replaces the exhaust silencers. Nitrogen oxides are reduced to nitrogen gas by spraying urea or ammonia into the gases before they pass through a catalytic converter. Reduction costs are generally below 600 euro per ton NOx reduced, lower if the equipment can be installed while the ship is being built. There are now more than fifty ships fitted for SCR. About half of them are Swedish, and most of the others are frequent operators at Swedish ports. This is largely a result of the environmentally differentiated fairway charges and port dues that has been used in Sweden in since 1998.

HAM, Humid Air Motor

A technique for preventing the formation of NOx, during combustion, by adding water vapours to the combustion air. Performance is unaffected either by the quality of the bunker oil or by engine workload. By reducing the consumption of fuel and lubricating oil, HAM has the advantage over Selective Catalytic Reduction (SCR) of somewhat lowering operating costs instead of increasing them. The method is able to reduce NOx by 70-80 per cent at a cost apparently similar to that of SCR.

Shore-side electricity

While docked at the port, ships shut off their propulsion engines, but use their auxiliary engines to power refrigeration, lights, pumps and other equipment. These auxiliary engines are usually powered by high-sulphur marine heavy fuel oil or in some cases by lower-sulphur marine gas oil, resulting in significant emissions of air pollutants. One possible alternative measure that specifically aims to reduce emissions from vessels in port is to plug them up to shore-side electricity so that they no longer need to run their auxiliary engines.

This solution is not has problems though – i. e. it requires investments and certain modifications to be made in the ports and on-board vessels.

Systems for supplying shore-side electricity is nothing new – they have been in use for decades in a few ports and for certain types of vessels. Experience from the Port of Goteborg, among others, has shown that the realities of handling shore-side electricity systems are simple, if modern high-voltage systems are used. The entire procedure for switching from on-board generated power to shore-side electricity is done in less than ten minutes, including the phasing in of the new electricity supply and closing down of the on-board auxiliaries.

In a recent Swedish study, the direct costs for shore-side electricity were found to be two to four times higher than the direct cost of generating electricity on-board by auxiliary engines running on heavy fuel oil. However, the study also evaluated the external costs that emissions of air pollutants give rise to through damage to health and the environment, and these are

significantly lower for vessels that are connected to a shore-side electricity supply. Depending on the fuel (Heavy Fuel Oil or Marine Gas Oil) and the type of shipping service examined, the external costs for on-board generation of electricity were found to be between 15 and 75 times higher than those for shore-side electricity connection. (The shore side electricity was assumed to be generated by modern coal-fired power plants).

A comparison between direct electricity generation costs and estimated external costs of on-board generation and shore-side electricity, respectively, showed that the benefits associated with shore-side electricity supplies clearly outweigh the costs.

The study concludes that shore-side electricity can effectively reduce air pollutant emissions and noise from vessels in port, thus providing environmental and health benefits. It is also recommended that if a wide-scale application of shore-side electricity systems were to be envisaged, it would be useful to develop a common international practice, or international standards, for such systems.

A Community strategy toreduce air pollution from ships

The EU strategy to reduce the emissions of air pollutants from sea-going ships was adopted by the European Commission in November 2002. It contains a broad series of objectives, proposed actions and recommendations for bringing about such reductions over the next 5-10 years. According to the Commission, the cost of reducing emissions from ships is considerably lower than that of further abatement on land. The strategy document includes a list of actions that the Commission itself

intends to take, as well as those it recommends to other parties. Here are some examples:

International action

Within the International Maritime Organization the European Commission will continue to press for tougher measures to reduce ships' emissions. It recommends member states to ratify MARPOL Annex VI as soon as possible, and to support a co-ordinated EU position pressing for tighter international standards in regard to the global sulphur cap and NOx emissions.

EU regulation on emission standards

On November 20, the European Commission published a proposal to amend directive 1999/32/EC so as to limit the sulphur content of marine fuels marketed and used in the EU. The recently adopted directive 2004/ 26/EC (amending directive 1997/68/EC) sets standards for emissions of NOx, PM and CO (Carbon Monoxide) for new non-road engines marketed in the EU, including engines for use aboard vessels operating on inland waterways. These new standards are gradually strengthened over the time period 2006-2014.

As concerns global emission standards for ships' engines, if the IMO has not proposed tighter international standards for NOx by the end of 2006, the Commission will consider bringing forward a proposal for reducing such emissions from seagoing vessels, in line with the proposed US standards put forward by the US Environment Protection Agency.

EU regulation on economic instruments

The European Commission has yet to come up with proposals, in the context of an EU framework for infrastructure charging, for the development of an EU system of differentiated charges for all modes of transportation. A charging scheme for maritime transportation will be part of that framework, and be developed on the basis of ships' environmental performance, including atmospheric emissions.

Later, the Commission considered the possibility of developing emissions trading regime (or regimes) to achieve incremental reductions in ships' emissions in EU sea areas, particularly for NOx. The feasibility of trading in ships' emissions will however first have to be demonstrated.

Voluntary measures

The European Commission urges the international bunker industry to make available significant quantities of marine heavy fuel oil with a maximum sulphur content of 1. 5 per cent in states bordering on SOx Emission Control Areas, and also to make available at least some marine fuel of any grade with a sulphur content of 1. 5 per cent in all world bunkering ports, so as to be able to supply ships destined for an SOx Emission Control Area. The Commission urges port authorities to consider introducing voluntary speed reductions, and to require, facilitate, or provide incentives for ships to use land-based electricity or clean on-board power while in port.

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