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PREVENTION OF AIR POLLUTION FROM SHIPS

Reduction of emissions of black carbon from shipping in the Arctic

Submitted by Norway, Sweden and the United States

SUMMARY

Executive summary:	This document discusses the impacts of black carbon (BC) emissions from shipping on the Arctic climate, the importance of that impact, and several approaches to reduce those emissions. This document also sets forth several potential initial proposals for action to reduce BC emissions from shipping that impact the Arctic that the Committee might consider
Strategic direction:	7.3
High-level action:	7.3.1
Planned output:	7.3.1.3
Action to be taken:	Paragraph 17
Related document:	MEPC 58/INF.21

Introduction

1 This document discusses the impacts of black carbon (BC) emissions from shipping on the Arctic climate, the importance of that impact, and several approaches to reduce those emissions. This document also sets forth several potential initial proposals for action that the Committee might consider to reduce BC emissions from shipping that impact the Arctic.

Brief Introduction to Black Carbon Impacts

2 Black carbon is a component of particulate matter (PM) and is produced by ships through the incomplete combustion of diesel fuel. Black carbon has a positive climate-forcing effect because it is dark in colour. It warms the atmosphere by absorbing incoming sunlight; heated air is available to move around the hemisphere as part of global circulation. Moreover, the impact of black carbon on climate is heightened by several factors:

.1 Black carbon's warming effect is especially important in the Arctic and within the Arctic Front which extends north of ~40 degrees latitude North. When deposited on snow and ice in the Arctic and lower latitudes, it darkens light surfaces and absorbs energy, causing snow and ice to melt, which further darkens the surface, resulting in the absorption of even more energy in a positive feedback loop.[1]

.2 The Arctic climate is a particularly important part of the global climate system, and the Arctic is warming at an unexpectedly fast rate.

.1 Over the past century, observed average temperature increases in the Arctic have been more than double the global average of 0.7 degrees C.

.2 Spring melt date at the North Pole this century is occurring seven days earlier than in the mid twentieth century.

.3 Arctic sea ice is in a state of ongoing decline, with an 11.7 per cent per decade rate of decline since 1979, and an especially sharp drop in 2007. Computer models have substantially under-predicted the speed and size of this decline.

.4 Many of Greenland's major outlet glaciers have seen rapid acceleration, thinning, and discharge this century; as these land-based glaciers melt, they contribute to global sea level rise.

.5 Warming temperatures trigger feedback loops that are already melting permafrost, where hundreds of billions of tons of carbon dioxide and methane (another highly potent greenhouse gas) are stored.

.3 Black carbon has a much shorter atmospheric lifetime (days to weeks) compared with CO_2 in which a portion of any pulse of emission remains in the atmosphere and heats the planet for 1,000 years or more. Black carbon's shorter lifetime means that the benefits of reductions will be felt much more rapidly in the Arctic and elsewhere.

3 The total warming effect of global BC emissions is estimated to be between 22% and 61% that of annual CO_2 emissions.[2] Over shorter time horizons, black carbon's climate impact is especially severe: it is estimated to cause 680 times more warming than the same amount of CO_2 over 100 years, and 2,200 times over 20 years.[3]

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[1] Although black carbon is co-emitted with organic carbon, the direct atmospheric effects of black carbon are eight to ten times more potent with regards to absorbing heat and energy than organic carbon is to reflecting heat and energy. *See* Bond, T. and Sun, H., "Can Reducing Black Carbon Emissions Counteract Global Warming," ES&T, August 2005.

[2] IPCC (2007): *Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* ("IPCC 2007"), available on the Internet at: http://ipcc-wg1.ucar.edu/wg1/wg1-report.html.
Ramanathan, V. and G. Carmichael (2008). "Global and regional climate changes due to black carbon", *Nature Geoscience* 1:221-27; Shindell, D and Faluvegi, G. (2009), "Climate response to regional radiative forcing during the twentieth century," *Nature Geoscience* 2:294-300.

[3] (Bond and Sun 2005)

4 Emissions of black carbon, as a constituent of PM, produce not only climate impacts, but also significant impacts on human health. These impacts include heart attacks, lung cancer, and other heart and lung damage up to and including premature death. Reduction of shipping PM emissions therefore will provide benefits to human health as well as climate.

Black Carbon Shipping Emissions

5 International shipping is a significant emitter of black carbon, emitting between 71,000 and 160,000 (metric) tonnes annually.[4] At present, marine vessels emit an estimated 2% of total global BC (and about 3% of CO_2). An estimated 85% of shipping emissions occur in the northern hemisphere, and the release of BC emissions in northern shipping routes affecting the Arctic is particularly damaging and magnifies their impact, as discussed above. Furthermore, as sea ice melts, more sea lanes open up. Although shipping emissions of BC in the Arctic region are relatively small at present, some estimates project they will increase by two to three times the global rate between now and year 2050.

6 Recent studies indicate that black carbon constitutes between 5% and 15% of world shipping emissions of particulate matter.[5] Black carbon, a product of incomplete fuel combustion, is dependent on engine type and combustion efficiency. A recent study found that medium speed marine engines typically used on tugboats, fishing vessels and ferries emit BC at more than twice the rate of slow speed engines used on large ocean-going ships (excepting containerships) and high speed engines used on passenger ships.[6]

Potential Approaches to Reduce Black Carbon Emissions

7 Emissions of black carbon are a result of incomplete combustion of the fuel. Combustion depends strongly on the air fuel ratio, fuel injection quality and the temperature and pressure of the air charge. Fuel grade has less influence than the aforementioned factors. It should be underlined though, that it is essential that the engine is optimized towards the fuel grade used. BC emissions are most prominent during start up and transient engine load. Reductions in visible smoke have been achieved successfully through in-engine measures where such reductions have been mandated, e.g., for certain cruise ships.

8 At this stage the co-sponsors do not want to be too descriptive in proposing reduction measures on ships, but opportunities to reduce fuel consumption from the world's shipping fleet can include:

.1 Vessel speed reduction: Fuel consumption increases with a power function of speed (approximating a cubic function in large cargo ships), so a 10% reduction in vessel speed may result in ~23% reduction in CO_2 emissions, while a 34% speed reduction (even assuming a 40% increase in the number of vessels) can reduce emissions by ~57%. Additionally, speed reductions will also significantly reduce BC provided the engine load is not reduced to a point where soot emissions increase significantly.

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4 Green, E., Winebrake, J. and Corbett, J. (2007). "Opportunities for reducing greenhouse gas emissions from ships," annex to document MEPC 58/INF.21; Lack, D. *et al*. (2008) "Light absorbing carbon emissions from commercial shipping." *Geophysical Research Letters*, Vol 35. Geophysical Research Letters, Vol. 35, L13815

5 Lack, D., *et al*. (2009) "Particulate emissions from commercial shipping; chemical, physical and optical properties." *J. Geophysical Research,* 114, D00F04, doi:10.1029/2008JD011300.

6 Lack (2009). Although higher BC emissions were found in ships burning lower sulfur fuel, these ships had predominantly medium speed engines, and the engines rather than the fuel likely produced the higher BC emission rates.

.2 Modifications to vessel and propeller design can reduce fuel consumption, these modifications may include: hull optimization (e.g., use of a stern flap which lengthens the bottom surface of the hull; replacement of the flat bottom hull surface with an air cavity system), propeller system improvements, propeller coatings, and a bulbous bow.

.3 Maximum use of alternate power technologies: one of the most promising is wind-sails and kites that can assist in ship propulsion, reducing fuel consumption and thus BC and other pollutants.

.4 Measures to improve ship routeing and logistics: Such measures include: planning to better utilize existing fleets; weather routeing to exploit favourable weather and currents; just-in-time routeing; reduced time in ports through optimal cargo handling, improved berthing, mooring and anchoring practices; and improved terminal operations to reduce delays.[7]

9 Apart from reducing BC and other GHG emissions by reducing fuel consumption, BC may also be reduced by the use of specific pollution control measures. These include:

.1 In-engine measures;
.2 Installation of diesel particulate filters (DPF);
.3 Use of water-in-fuel emulsification on demand; and
.4 Replacement of conventional fuel valves with slide valves.[8]

10 In-engine measures to reduce smoke include improved fuel injection systems (e.g., common rail) modified turbochargers and more. Several engine manufacturers presently use in-engine technology providing engines with lower smoke emissions as compared to standard engines.

11 Diesel particulate filters (DPF) are after-treatment devices that are particularly effective at controlling BC, reducing emissions by 95 to 99.9% by mass (with 70-95% reductions in total PM).[9] This technology is suitable only for high grade (ideally ultra low sulphur automotive fuel) distillate fuels and cannot be used together with residual fuels.

12 Emulsification on demand consists of introducing water into the fuel prior to injection into the combustion chamber, and is estimated to reduce PM and BC by two to three times the amount of water introduced. Water injection also reduces NO_x emissions by an amount roughly equal to the amount of water used.[10]

13 Slide valves produce more complete combustion than conventional valves, reducing PM and BC by 25% or more. NO_x is also reduced, by about 10-25%. Slide valve replacement is extremely cost-effective, having a total incremental installation cost of less than $700 per valve.[11] Slide valves cannot be used on all engines.

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7 Annex to document MEPC 58/INF.21.

8 Winebrake, J., Corbett, J. & Green,E. "Black carbon control costs in shipping", prepared for ClimateWorks Foundation (2009).

9 See, e.g., annex to document MEPC 58/INF.21. Oxidation catalysts reduce some PM constituents, but do not reduce BC.

10 Winebrake, Corbett and Green (2009).

11 Entec UK Limited (2005), Final Report for European Commission Directorate-General-Environment, "Service Contract of Ship Emissions: Assignment, Abatement and Market-based Instruments".

Proposal

14 Emissions of black carbon have serious impacts on the Arctic, and the co-sponsors reiterate the following main points:

.1 the Arctic climate is warming much faster than the rest of the planet;

.2 rapid melting of Arctic land- and sea-ice is accelerating that warming;

.3 black carbon emissions, especially when deposited on land- and sea-ice, are a significant contributor to that warming and melting;

.4 reductions of black carbon now, can provide short-term climate responses that are absolutely necessary to forestall a climate "tipping point", thereby providing the climate "breathing time" for the needed reductions in CO_2 to take hold over the longer term; and

.5 reductions of black carbon will have positive effects on human health.

15 In light of the above, and because shipping is a contributor to black carbon emissions, and because shipping traffic in the Arctic is expected to grow substantially as the ongoing melting process opens up sea lanes in the region, it is important that IMO considers actions to respond to the effects described above.

16 Consistent with the work being undertaken on SO_x and NO_x reductions, it is therefore proposed that the Committee discusses how to address this air pollutant by examining potential measures to be recommended or required to significantly reduce BC emissions from shipping having an impact in the Arctic. Such measures should not impose other environmental risks to the Arctic Environment.

Action requested of the Committee

17 The Committee is invited to consider the information and proposal presented in this document and take action as appropriate.

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