Assessment of global particle number emissions from shipping and effect of scrubbers

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Globally, ship exhausts are the main source of particles over large areas in open seas and coastlined, and the particles emitted both contribute to impaired air-quality and have climatic effects. Combustion aerosols indirectly affect climate by influencing the formation of clouds and their light scattering properties. In order to accurately estimate the climate-forcing impacts of ship emissions, particle number (PN) and size distribution (PSD) of the emitted aerosols are important, further to total particle mass (PM). From 2020 onwards, ships are forbidden to burn fuel with sulphur content over 0.5%, unless they apply scrubbers for SO_2 abatement.

Particle measurements were conducted in laboratory on 1.6MW marine engine and 6 different fuels with varying properties and sulfur contents were tested ath low and high load points. In addition, measurements were conducted on-board a cruise ship, before and after scrubber, from the exhaust lines of two main engines (ME1 and ME2, applying SCR). Identical sampling setup was applied in all campaigns, consisting of a porous tube diluter together with residence time chamber and ejector diluter, which simulates atmospheric dilution conditions [1]. PN and PSDs were studied by scanning mobility particle sizer and condensation particle counters (CPC). To study the effect of scrubber on non-volatile particles, a catalytic stripper was applied. The obtained PN emission factors were compared to ship plume observations conducted on the Finnish coastline, by chasing ship plumes by aircraft. STEAM ship emission model was applied to assess the globally distributed PN emissions from international shipping and estimate the influence of the sulfur regulation.

The PN emission factors for different fuels varied between $1.38\text{-}5.83\times10^{16}$ 1/kgfuel [2]. The scrubber efficiently removed volatile particles in nucleation mode size range and reduction was larger with engine applying SCR [3]. The global PN emissions from shipping are localized close to coastal lines and busy port areas, but significant emissions exist also on open seas and oceans. The global annual PN produced by marine shipping was 1.2×10^{28} ($\pm0.34\times10^{28}$) particles in 2016, which is of same magnitude with total anthropogenic PN emissions in continental areas [4]. The potential to reduce global PN emissions from shipping depends strongly on the adopteed technology mix, and is possible with wide adoption of natural gas and scrubbers, but no significant decrease is expected if heavy fuel oil is mainly replaced by low sulfur residual fuels.

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