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# Nanoparticles from Shipping and Road Traffic

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**Abstract**

In the urban environment road traffic is the dominant source of aerosol particles while in coastal and harbour areas shipping is also a significant source. For shipping there are no direct regulations regarding particle emissions. For road traffic the emissions of particle mass has been regulated for over two decades but only during the last few years particle number has been included in emission regulations. Generally, nanoparticles are better described by their number rather than mass since they contribute insignificantly to the total particle mass of urban particles. Furthermore, particle number is believed to be a better metric for describing health effects than particle mass. Particle number and mass of the nanoparticles is however more difficult to measure both because of their small size but also because they are part of a highly dynamic system with constant exchange with the gas phase.

The studies described in this thesis were conducted with the aim of increasing the knowledge on the emissions of nanoparticles from shipping and city transit buses. The focus has been on size resolved particle number emissions. The evolution of nanoparticles was studied by conducting measurements by extractions from the inside of the exhaust system and from the exhaust plume.

Emissions of nanoparticles depend on combustion conditions, exhaust aftertreatments, the fuel and ship/vehicle variations. In this study engine load and engine speed was found to be the most important factors studying individual vehicles or ships. For example, manoeuvring of a ship in the port areas was found to contribute to up to a factor of 64 times higher particle number emissions than during stable engine load at open sea. It was found the variation between vehicles or ships was the most important factor when studying a fleet of vehicles or ships operating on different fuels and/or exhaust aftertreatments. For example, from a selection of 35 buses a few diesel fuelled buses were responsible for most of the particle mass emissions while a few buses fuelled with compressed natural gas were responsible for most of the particle number emissions. Controlling these extreme emitting individuals or specific operating conditions could be an effective way of reducing the total emission of nanoparticles.

Nanoparticles extracted from the exhaust system are different compared to the nanoparticles found in the exhaust plume. In the ship exhaust system a soot mode was often found together with a volatile nucleation mode. In the ship exhaust plume the volatile nucleation mode coagulated quickly leaving soot covered with volatile material. Soot emissions were lower for the studied buses which supress condensation and the lower total number concentrations in the bus emissions reduce the rate of coagulation. Nucleation mode particles for the studied buses were found both in the exhaust system and in the exhaust plume. Nucleation versus condensation of volatile material has implications for the measured particle number and in addition, soot covered with volatile material has a denser structure than soot without condensable material.

Non-volatile particles with a diameter of ~10 nm were found in the ship plume measurements which were not present in the on-board measurements. A hypothesis of organo-sulphates being formed in the exhaust plume was presented which could explain the formation of these particles. This emphasis that processes in the atmosphere can be of importance but they will not be covered in on-board or laboratory measurements.



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