Physicochemical and optical properties of combustion-generated particles from Ship Diesel Engines

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Shipping contributes significantly to the anthropogenic burden of particulate matter (PM), and is among the world's highest polluting combustion sources per fuel consumed (Popovicheva et al., 2009). Moreover, ships are a highly concentrated source of carbonaceous particulate pollutants which are emitted into clean marine environments (e.g., Artic region) and harbor areas(Moldanova et al., 2013). Shipping utilizes heavy fuel oil (HFO) which is less distilled compared to fuels used on land and few investigations on shipping related PM properties are available. BC is one of the dominant combustion products of ship diesel engines and its chemical and microphysical properties have a significant impact on climate by influencing the amount of albedo reduction on bright surfaces such as in polar regions (Quinn, 2008).

We have carried out a campaign to characterize the PM emissions from medium-sized marine engines in Gunsan, Jeonbuk Institute of Automotive Technology. The ship-diesel PM characteristics depend on (1) fuel sulfur content (HFO vs. ULSD) and (2) engine conditions (Running state vs. Idling state) which are being analyzed in order to understand how these characteristics influence the BC formation process and properties. Scanning electron microscopy (SEM), high-resolution transmission electron microscopy (HRTEM), energy-dispersive X-ray spectroscopy (EDX) equipped with HRTEM and Raman spectroscopy were used for physicochemical analysis. Optical properties, which are ultimately linked to the snow/ice albedo decrease impacting climate, were assessed as well (Ramanathan and Carmichael, 2008).

Particles generated from different combustion sources and conditions demonstrated great variability in their morphology, structure, and composition. PM generated under high engine temperature conditions had typical features of soot, e.g., concentric circles comprised of closely packed graphene layers, however PM generated by the idling state at low combustion temperature was characterized by amorphous and droplet-like carbonaceous particles with no crystalline structure and were generally formed by the condensation of low-volatile species at low-temperature (~300–800ºC) combustion conditions. Significant differences in optical properties depending on the combustion conditions were also observed. Particles from running conditions showed wavelength-independent absorbing properties, whereas the particles from idling conditions showed enhanced absorption at shorter wavelengths, which is characteristic of brown carbon (Kim et al., 2015). Main light absorbers at short wavelengths are proposed for high molecular weight organics (e.g., PAH), a result of agglomeration and condensation of unburned organics on quartz fiber filter. Regarding different fuel types (ULSD vs HFO), distinctive structure differences were not observed, but EDX results showed that PM generated by HFO combustion has higher sulfur content (1 %) in the particle phase whereas ULSD generated 100% carbon composed PM.

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