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PII: S0021-8502(18)30092-2  
DOI: <https://doi.org/10.1016/j.jaerosci.2018.09.005>  
Reference: AS5336

To appear in: *Journal of Aerosol Science*

Received date: 14 March 2018  
Revised date: 13 September 2018  
Accepted date: 14 September 2018

Cite this article as: Päivi Aakko-Saksa, Päivi Koponen, Minna Aurela, Hannu Vesala, Pekka Piimäkorpi, Timo Murtonen, Olli Sippula, Hanna Koponen, Panu Karjalainen, Niina Kuittinen, Pavlos Panteliadis, Topi Rönkkö and Hilikka Timonen, Considerations in analysing elemental carbon from marine engine exhaust using residual, distillate and biofuels, *Journal of Aerosol Science*, <https://doi.org/10.1016/j.jaerosci.2018.09.005>

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# Considerations in analysing elemental carbon from marine engine exhaust using residual, distillate and biofuels

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## Abstract

Elemental carbon (EC) concentrations in the exhaust of a medium-speed marine engine was evaluated using thermal-optical analysis (TOA). Particulate matter (PM) samples were collected at 75% and 25% engine loads using residual and distillate fuels with sulphur contents of 2.5%, 0.5% and 0.1%, and a biofuel (30% of bio-component). The EC analysis of PM samples from a marine engine proved to be challenging. For example, transformations of structure of the sampled particles in the inert and the oxygen mode were observed for marine engine exhaust samples. The relationship between constituents present in the samples from the marine engine using different fuels, and phenomena observed in the thermograms are discussed. Temperature protocol selection and sample pre-treatment (extractions and drying) affected the reported EC mass. Modifications in the methodology were suggested to increase the accuracy of the analysis. Repeatability and reproducibility of the EC analysis was studied in the round-robin of three laboratories.

Keywords: Elemental carbon EC; thermal-optical analysis TOA; thermogram; marine engine; fuel; round-robin

## 1 Introduction

Black carbon (BC) is the second largest anthropogenic contributor to climate change, and is also associated with serious adverse health effects (Bond et al., 2013). Regulation for ship BC is anticipated, as ships are important emitters of BC particularly in Arctic areas (Quinn, Stohl, Arneth, & Berntsen, 2011). BC is optically measured carbon, which strongly absorbs visible light. Absorbing species are also coloured organic compounds called brown carbon (BrC), e.g., refractory high molecular-weight polymeric or polycyclic aromatic compounds and humic-like substances. In exhaust from marine engines, BrC is typically formed in combustion processes, but can also form, e.g., when sulphates react with organic compounds in low humidity (Andreae & Gelencser, 2006; Bond et al., 2013; Collaud Coen et al., 2010; Kupiainen & Klimont, 2007; Lim et al., 2014; Yang, Howell, Zhuang, & Huebert, 2009). Although not commensurable by definition, elemental carbon (EC) is often used synonymously with BC. EC is refractory, non-volatile material in particulate matter (PM) measured with thermal or thermal-optical analysis (TOA) methods based on the evolution of carbon species in different temperatures (Bauer, Yu, Cary, Laulainen, & Berkowitz, 2009; Birch & Cary, 1996; Turpin, Cary, & Huntzicker, 1990; Watson, Chow, & Chen,

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