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Atmospheric reactivity of brake wear: implications for predicting and improving air quality

Background: Particulate matter (PM) is a concern for human health, visibility, and climate. In urban environments, one of the largest sources of PM is traffic, classified as tailpipe or non-tailpipe (brake, tire, and road abrasion) emissions. Due to regulations and technological improvements related to tailpipe emissions, it is predicted that by 2030 up to 90% of traffic PM will be from non-tailpipe emissions. One of the largest sources of these non-tailpipe emissions is brake wear. Studies performed to date have investigated the size, quantity, composition, and toxicity of emitted brake wear. However, the reactivity has not been investigated. In this study, we will quantify the interaction of ozone, an important urban pollutant, with brake wear. This interaction was chosen as other types of PM containing similar components to brake wear, organics and metal oxides, have been shown to react with ozone and this reactivity is enhanced when exposed to light. Understanding the interactions of PM with pollutant gases is important because they can influence air quality and climate by altering the concentration of the gas, and the toxicity and climate related properties of the PM.

Methods: Brake wear particles were obtained by grinding a set of five commercial brake pads from different manufacturers and of different types (two ceramic, two semi-metallic, and one organic). The particles were characterized using inductively coupled plasma mass spectrometry (ICP-MS) to determine elemental composition and thermogravimetric analysis (TGA) to determine organic carbon and graphite content. The interaction of brake wear with ozone was quantified using a coated-wall flow tube, which consist of a tube coated with particles that is exposed to ozone. The concentration of ozone, monitored after the tube, decreases if an interaction occurs and an uptake coefficient, used in atmospheric models, can be calculated. Studies were performed over a range of relative humidities (RH) to assess different atmospheric conditions, and under dark and light to assess potential photochemistry.

Results: We found that the uptake coefficients for ozone on all brake wear samples was at least an order of magnitude larger than those for road dust and mineral dust samples previously studied by our group. Additionally, the reactivity of our samples was enhanced when exposed to light. Interestingly, we also found that reactivity generally increased with increasing RH, which is opposite the behaviour often observed for inorganic PM. Despite the variable composition of the samples, the uptake coefficients were reasonably similar.

Conclusions: For the first time we showed that brake wear is reactive in the atmosphere. The similar reactivity of the samples has the potential to simplify the implementation of brake wear-ozone interactions in atmospheric models. Additionally, our results, in combination with toxicity and emission factor studies, will be important to the assessment of current regulations for ozone and to the development of future regulations for brake wear emissions leading to improved air quality.