使用 GED-ICP-MS 對 $PM_{2.5}$ 金屬成分進行即時連續監測
Real-time monitoring of metal components in $PM_{2.5}$ using GED-ICP-MS

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Abstract

Particulate matters with sizes below 2.5 μm ($PM_{2.5}$) in the ambient atmosphere can cause a great harm to human health. The metal composition of $PM_{2.5}$ provides a fingerprint that can be used to identify the origins of $PM_{2.5}$. However, the traditional offline method, which involve collecting $PM_{2.5}$ on membrane filters, followed by digestion and ICP-MS analysis is time-consuming with a serious lag time. The Offline method compresses the $PM_{2.5}$ collected from different sources for long time into an average concentration, which cannot consider change of time. Online direct analysis by ICP-MS offers a tremendous opportunity for highly time-resolved near real-time monitoring of atmosphere $PM_{2.5}$ metal concentrations. However, the atmospheric composition is incompatible with ICP-MS that requires argon for effective plasma ignitions. In this work, a gas exchange device (GED) in which gases in atmospheric samples flowing within a ceramic tubular porous membrane (pore size 100 nm) were replaced with argon that flows over the outer membrane surface was made and connected to ICP-MS. The feasibility of GED-ICP-MS for the online $PM_{2.5}$ metal analysis was tested by monitoring $PM_{2.5}$ metals including Al, Pb, Cu, Fe, Cr, and Zn in the laboratory air. An initial test showed detectable signals of PM metals in the indoor air samples in large contrast to those of HEPA-filtered pure argon as blank. We established a metal mass calibration method by using aqueous metal standards. The mass-to-signal ratio calibration curve was established by nebulizing varying amounts of metal standards into the sample flow before entering plasma and the resulting signal areas were integrated. Zero air, filtered air, and unfiltered air were used to establish the mass-signal calibration curves with results showing a significant matrix effect. The greater sensitivity was observed with the filtered air, that was 1.4 times and 2.5 times higher than those of zero air and unfiltered air. This phenomenon likely suggests that the calibration curve is better established by adding metal standards into unfiltered air sample. Finally, the results of the 6-hour continuous monitoring of indoor air $PM_{2.5}$ showed that the average concentrations of Fe, Zn, Al, Cu, Pb and Cr in $PM_{2.5}$ were 80.8, 76.2, 54.4, 5.5, 1.1, and 0.4 ng/m^3, respectively. The online monitoring result were compared with those by the traditional filter collection method. The $PM_{2.5}$ metal concentrations measured with the filter method were all below the detection limit except for Fe and Zn, demonstrating the high sensitivity of GED-ICP-MS method.

關鍵字：高時間解析監測、痕量金屬、ICP-MS 即時分析
Key works: Highly time-resolved monitoring, trace level metal concentration, Online ICP-MS