National Aeronautics and Space Administration

FY24 R&TD Innovative Spontaneous Concepts (ISC)

Near real-time in-situ chemical speciation of particulate matter air pollution using microdevice technologies

Principal Investigator: David Diner (329)**; Co-Investigators:** Sina Hasheminassab (398), Fernanda Mora (389), Aaron Noell (389), Peter Willis (389), Christopher Oxford (Washington University)

Strategic Focus Area: Innovative Spontaneous Concepts

Objectives: The objective of this work was proof-of-concept demonstration of a moderate-cost particulate matter (PM) sampling system capable of measuring the concentrations of inorganic ions including sulfate, nitrate, ammonium, and soluble metals in the field with accuracies and sensitivities comparable to currently operational networks. Existing filter-based measurement systems operated by the US EPA are labor-intensive and costly, provide speciated PM data on daily-averaged resolution only every 3rd or 6th day at sparsely distributed sites, and have latencies of at least 6 months before laboratory chemical analyses of the collection media are available. Such limitations preclude data usage for air quality forecasting or management of short-term hazardous air pollution events.

Background: Ambient (outdoor) airborne PM is the top environmental health risk worldwide. While most surface-based networks measure total mass concentration at point locations, large areal coverage of PM chemical composition with spatial resolution of a few kilometers is essential for assessing the relative toxicities of various PM constituents, which are currently poorly understood. Satellite-based instruments can provide the necessary spatial and temporal coverage; however, aerosol information derived from remote sensors is only indirectly related to M chemical composition, requiring measurements from surface-based particle speciation samplers to train PM prediction models and generate maps.

Approach and Results: This study capitalized on JPL's previous work on capillary electrophoresis analyzers developed for planetary life detection. Ambient $PM_{2.5}$ samples dissolved in water were analyzed using capillary electrophoresis with capacitively coupled contactless conductivity detection (CE-C^4D). CE separations occur within small diameter glass capillaries filled with a background electrolyte (see Fig. 1). A sample is injected at one end of the capillary and a voltage is then applied between both ends, which generates a bulk electroosmotic flow (EOF) in which molecules separate according to differences in mobility (a function of charge/size). C^4D is a simple and universal detector for charged compounds in CE; its miniaturized electronic packaging, low power, and low reagent consumption make it a preferred detection technique for portable point-of-use applications. Example electropherograms are shown in Fig. 2. Anion or cation analysis takes ~15 minutes.

Previously collected ambient $PM_{2.5}$ samples dissolved in water were obtained from Washington University as surplus from routine analyses of particles collected on filter media on the roof of JPL B301 as part of JPL's Multi-Angle Imager for Aerosols (MAIA) project. Results obtained by CE-C^4D were compared against results obtained using ion chromatography (IC) at Washington University (Figs. 3 and 4). Good correlation, even at low concentrations, was obtained for nitrate and sulfate. The correlation for ammonium is not ideal but this may be due to volatilization over time since the filters were analyzed much earlier by IC. For metal ions, the best results were obtained for sodium, though the poorer correlation merits further investigation. While the CE-C^4D analysis done for this study used a commercial laboratory system (Fig. 1C), near-real time in-situ analysis in the field is desirable for future development. An example of the compact type of instrument that could be developed is shown in Fig 1D.

Significance/Benefits to JPL and NASA: This work is aligned with JPL's focus on increasing our understanding of air quality, enabling better monitoring, and improving our understanding of air quality events that impact human health. Satellite missions such as MAIA offer a practical approach to mapping speciated PM at neighborhood scale, but spaceborne measurements must rely on surface monitors to transform the satellite aerosol retrievals into near-surface PM. Without reductions in cost and complexity of the surface monitors, global coverage would be impractical.

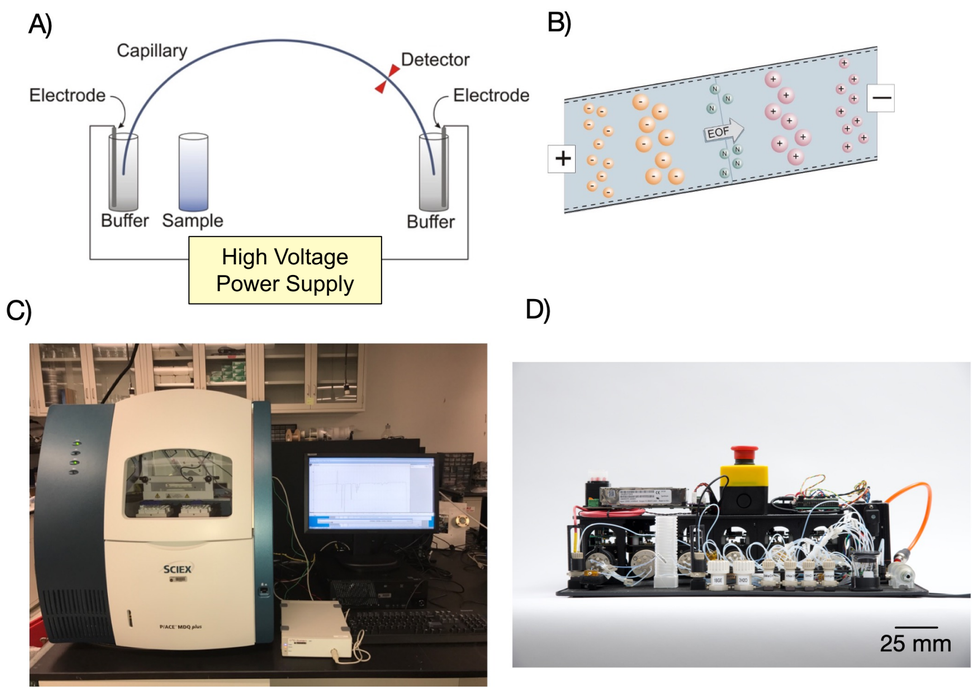

Figure 1. A) Diagram of CE system. B) Principle of capillary electrophoresis ion separation. C) Photograph of the commercial CE instrument used in this study. D) photograph of a compact automated CE instrument developed at JPL.

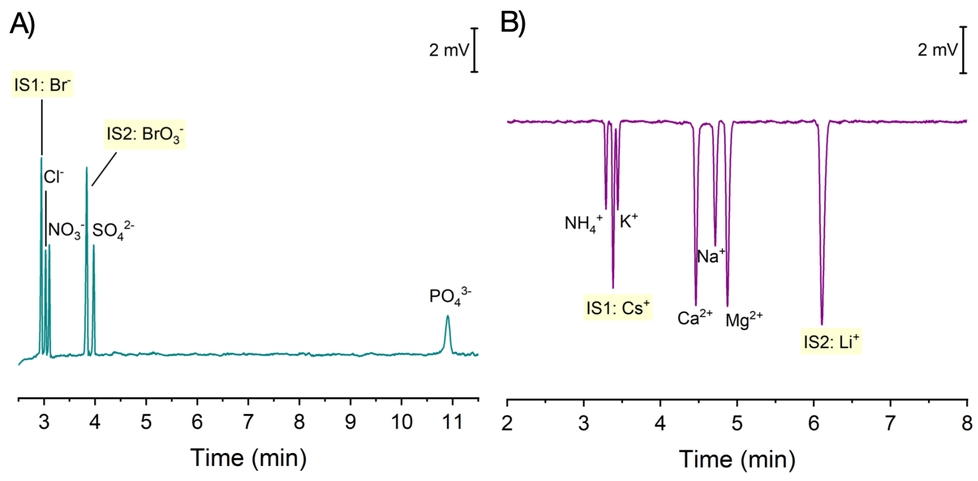

Figure 2. Example CE separations for A) anions and B) cations.

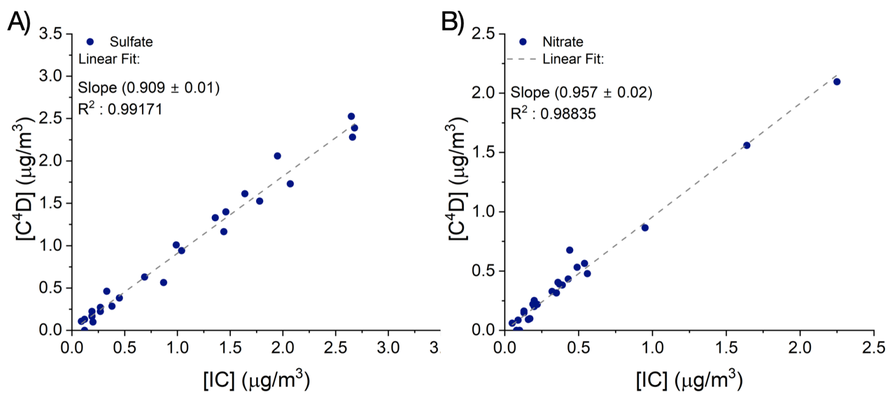

Figure 3. Correlation of CE-C^4D results at JPL with IC results obtained at Washington University for $PM_{2.5}$ for (A) sulfate and (B) nitrate ions.

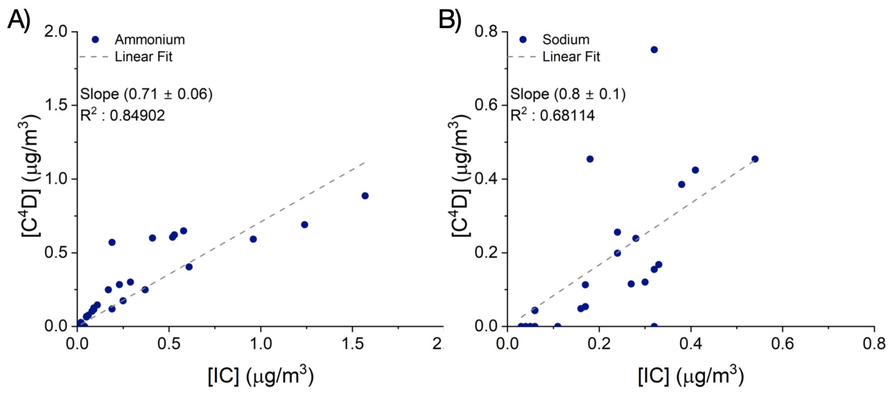

Figure 4. Correlation of CE-C^4D results at JPL with IC results obtained at Washington University for $PM_{2.5}$ for (A) ammonium and (B) sodium ions.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

RPD-084 Clearance Number: CL#24-5186

Copyright 2024. All rights reserved.

PI/Task Mgr. Contact Information: *(818) 354-6319; David.J.Diner@jpl.nasa.gov*