NEW INTERPRETATION OF DMA DATA THAT MAKES REALISTIC CHARACTERIZATION OF DIESEL EMISSION POSSIBLE: THEORY OF IDEALIZED AGGREGATES

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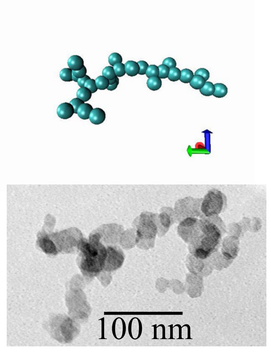
Motivation

Differential mobility analyzers (DMA) are routinely used to measure ultrafine aerosol number distributions. Current methods are based on spherical particle assumption. Aggregate morphology is the natural state of diesel emission solid particles. We present a novel method to determine the ultrafine aggregate number, surface area and volume distributions from DMA data.

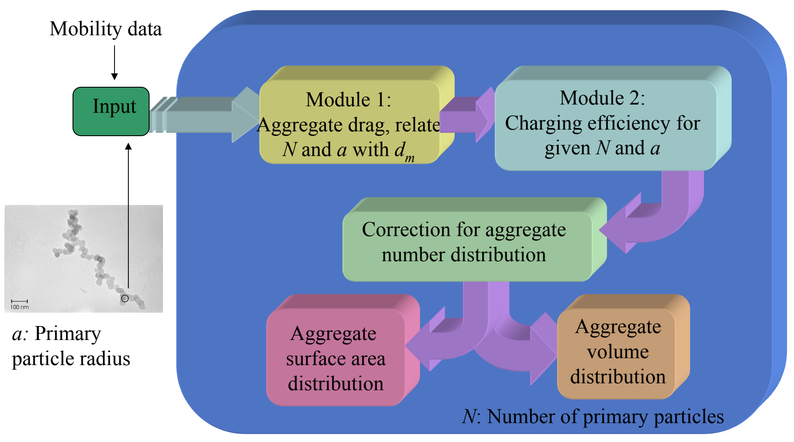
Theory of Idealized Aggregates (IA)

Lall and Friedlander (2006)

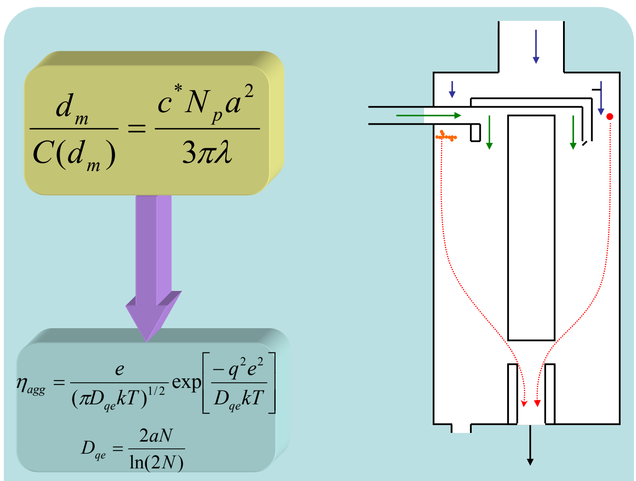


Idealized Aggregates:

- Uniform primary particle size
- Primary particles much smaller than mean free path of the gas
- Transparent structure:
  - Fractal dimension less than 2



Patent pending

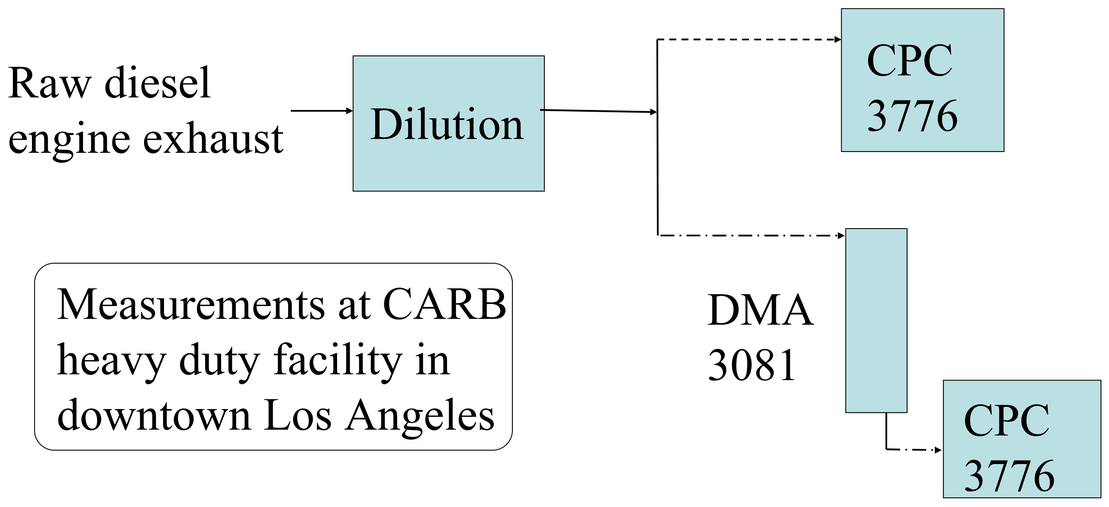


Aggregates and spheres with the same mobility diameter have **equal migration velocities**

Applications of IA Theory

- More accurate estimates of aggregate number, surface area and volume (or mass) distributions from DMA data.
- Estimates of total number concentration of solid spheroidal nanoparticles directly emitted from the diesel engine before aggregation: A conserved quantity.

Diesel Aggregate Emission Measurement

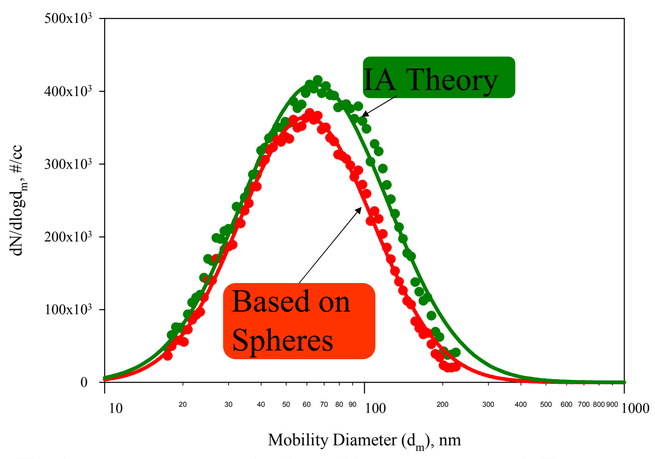


Measurements at CARB heavy duty facility in downtown Los Angeles

Measurement conditions:

- Heavy duty diesel engine
- Steady state operation at idle, 30, 40 and 50 mph.
- Sufficient dilution and residence time to eliminate volatile particles: Single mode corresponding to aggregates composed of solid particles is observed. The mode does not change upon further dilution.

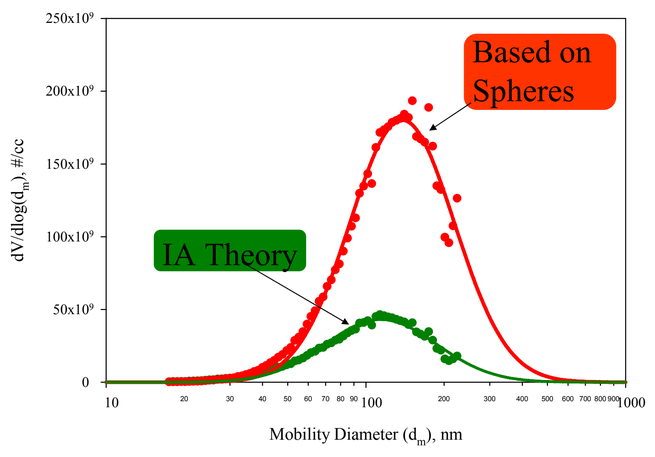
Number Distributions



Primary particle diameter: 17 nm

	Total Number (#/cm^3)
IA Theory	2.73×10^5
Based on Spheres	2.29×10^5
Direct CPC	2.77×10^5

Volume Distributions



	Total Volume (nm^3/cm^3)
IA Theory	2.17×10^{10}
Based on Spheres	7.97×10^{10}

Summary

- The IA theory is verified experimentally by Lall *et al.* (2006) for laboratory silver aggregates and literature data on diesel aggregates.
- The total number concentration based on IA theory in good agreement with that measured directly by the CPC: Further verification of IA theory.
- The total ultrafine solid nanoparticle volume is determined from IA theory. The volume based on spheres with diameter equal to the mobility diameter was grossly overpredicted.

Implementation of IA Theory in TSI Aerosol Instrument Manager Software: Chain Aggregates

The new software provides the idealized aggregate limit that can be compared with current results based on spherical particles. Further research is required for mixed aerosol composed of both spherical particles and aggregates.

References

Lall, A. A., and Friedlander, S. K., "On-line Measurement of Ultrafine Aggregate Surface Area and Volume Distributions by Electrical Mobility Analysis: I. Theoretical Analysis", Journal of Aerosol Science, 27 (2006) 260-271.

Lall, A. A., Seipenbusch, M., Rong, W. and Friedlander, S. K., "On-line Measurement of Ultrafine Aggregate Surface Area and Volume Distributions by Electrical Mobility Analysis: II. Comparison of Measurements and Theory", Journal of Aerosol Science, 27 (2006) 272-282.