APPLICATION NOTE

NIKIRA LABS – AN04 - OEA

Nikira Labs

App Note Series: Optical Extinction Analyzers

Using the Novel OEA Technology to Monitor Indoor Particulate Dispersion

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Introduction

The COVID-19 pandemic has dramatically increased the interest in studying indoor aerosol generation, transport, and dissipation[1]. Conventionally, the dispersion and settling of indoor aerosols has been measured using photometers and nephelometers. In this application note, we demonstrate the employment of a Nikira Labs OEA-532 Optical Extinction Analyzer to accurately measure aerosol dispersion and dissipation in an indoor environment.

Experimental Setup

Four OEA-532 analyzers (Demo 1, Demo 2, Demo 3, and Nik 1) were placed ~10 meters from a laser cutter in an open-area laboratory. Air circulation in the room was facilitated by a HEPA-filtered air conditioning unit. The laser cutter was used to cut 1/8" birch for ~5 minutes, thus creating fine particulate aerosols in the laboratory[2]. The optical extinction in the laboratory was measured prior, during, and after the laser cutting activity by all four analyzers for a total time period of ~12 hours.

Results & Discussions

The measured optical extinction as a function of time is shown in Figure 1. Note that there is a sharp rise when the laser cutter is activated, followed by a nearly exponential decay as particulate matter in the room is evacuated, filtered, or deposited out. The decay constant is 41 minutes, demonstrating the long residence time of particulate matter in the room despite active air circulation (air conditioning). Moreover, all four OEA-532 analyzers measured the same value for

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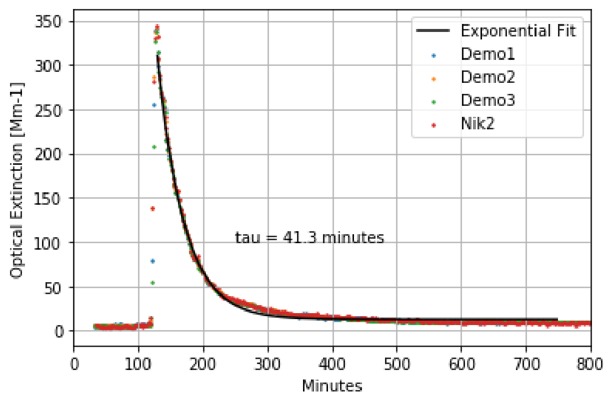
[1] Kohanski, M.A., Lo, L.J. and Waring, M.S., 2020, October. Review of indoor aerosol generation, transport, and control in the context of COVID-19. In *International forum of allergy & rhinology* (Vol. 10, No. 10, pp. 1173-1179).
[2] O'Neill, K., 2017. *Laser-Generated Airborne Contaminants from A Desktop Laser Cutter and Engraver*. The University of Oklahoma Health Sciences Center.

optical extinction (Figure 2), confirming that the analyzer is providing reproducible results, over this wide dynamic range and notably without the need for any prior calibration.



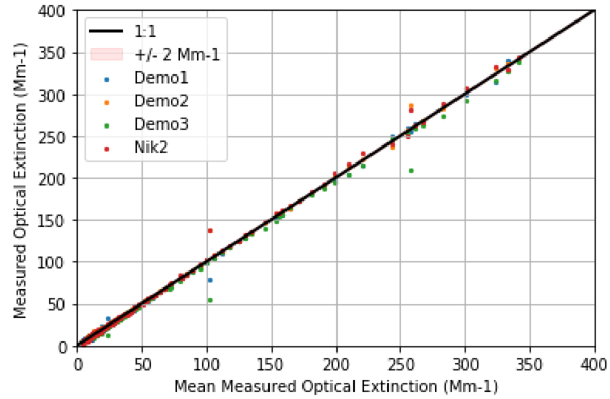


Figure 1: (left) Measured optical extinction from all four analyzers versus time. The particulate matter was evacuated (or deposited) with a single-exponential time constant of 41.3 minutes.

Figure 2: (right) Comparison of all four OEA-532 analyzers shows excellent agreement over this wide dynamic range.

Previous work[3] has shown that total optical extinction can be used to estimate $PM_{2.5}$ mass concentration, $[PM_{2.5}]$, via the following formula:

$$[PM_{2.5}] = \frac{1}{\alpha}\left(\frac{b_{ext}}{f(RH)} - \varepsilon\right)$$

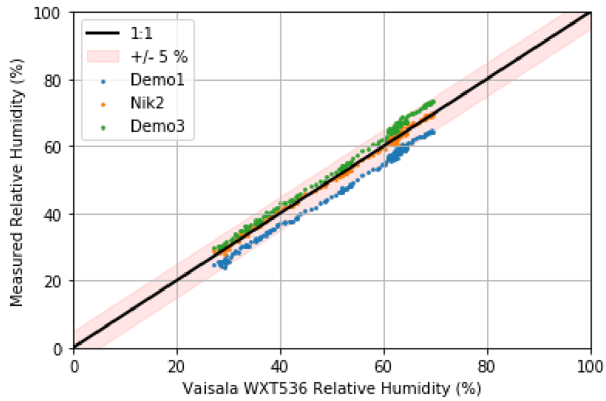
where α is the mass scattering efficiency at the site, b_{ext} is the measured optical extinction, f(RH) is the hygroscopic enhancement factor for aerosol total scattering, and ε is the optical extinction due to non-aerosol species (e.g., ambient gas scattering or absorption). Note that, since the OEA-532 measures b_{ext} of just the aerosol species (e.g., the gas contributions are automatically factored out), then $\varepsilon = 0$. Following Reference 3, f(RH) can be expressed as a function of relative humidity (RH):

$$f(RH) = \frac{1.03}{(1 - RH)^{0.183}}$$

Thus, in order to estimate $[PM_{2.5}]$ from the measured values of b_{ext}, we must also measure the relative humidity, RH. The OEA-532 analyzer includes a relative humidity sensor in the computer stack. This sensor is typically warmer than the inlet temperature of the instrument, and the measured relative humidity must be corrected by this temperature difference. The OEA-532

[3] Ji, D., Deng, Z., Sun, X., Ran, L., Xia, X., Fu, D., Song, Z., Wang, P., Wu, Y., Tian, P. and Huang, M., 2020. Estimation of PM 2.5 Mass Concentration from Visibility. *Advances in Atmospheric Sciences*, *37*, pp.671-678.

relative humidity was validated by comparing three OEA units to a Vaisala WTX-536 (Figure 3). The calculated relative humidity values of the OEA-532 analyzers were found to be within ±5% of the Vaisala reading. Using these readings and the referenced value for the mass scattering efficiency (α = 4.127 m^2/g), [$PM_{2.5}$] was estimated as shown in Figure 4. These values are consistent with other indoor air readings in polluted zones.



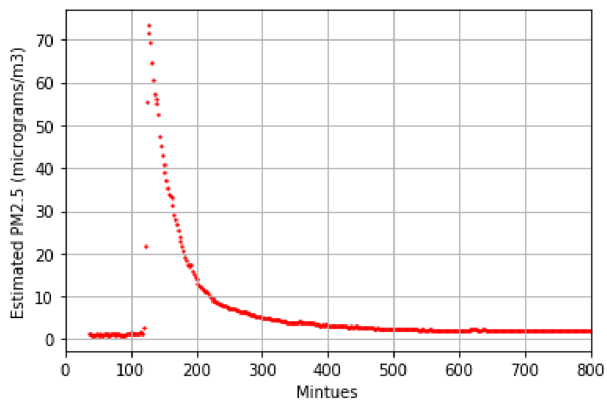


Figure 3: (left) The measured relative humidity provided by the OEA-532 is in good agreement with an independent reading from the Vaisala WXT536.

Figure 4: (right) Estimated PM2.5 mass concentration versus time as described in the text.

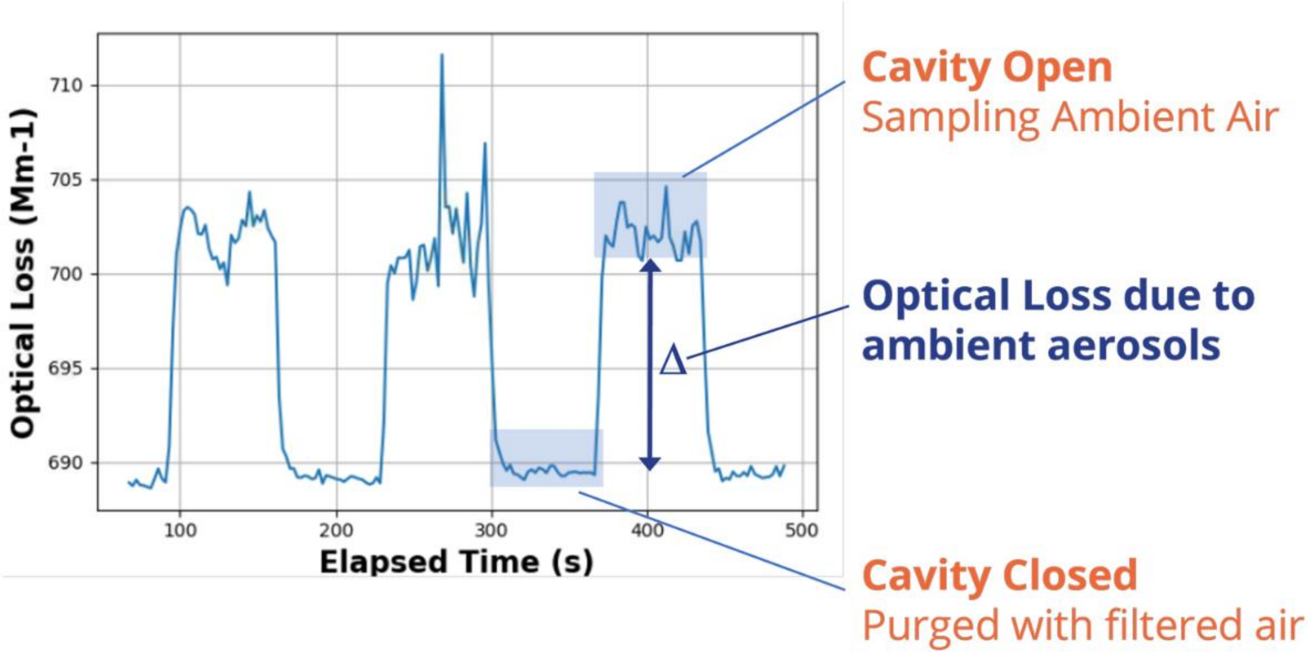
Further Work

This work can be extended and modified in a variety of ways, including:

- Measuring other indoor phenomenon under various room conditions.
- Validating and refining the estimation of $PM_{2.5}$ from optical extinction measurements.
- Extending the measurements to other sporadic emitters (e.g., roadside monitoring).

How Does the OEA Work?

1. Ambient air is pulled through a duct by fans at a speed of ~1 m/s.
2. Open-path cavity ringdown spectroscopy is used to make a direct measurement of the optical extinction coefficient (beta) in the sample.
3. The duct is periodically closed and the cell is purged with filtered air to a background measurement.
4. The difference between the open and closed duct values provides a direct, calibration-free measurement of the aerosol optical extinction.



The OEA Harnesses 3 Technologies: