Portable Air Cleaner Test Report
Intellipure Compact Air Purifier
August 2021 (Amended August 6, 2021)

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http://built-envi.com/portfolio/air-cleaner-testing

Test Description

As a result of recent global indoor air quality challenges, including the infiltration of smoke from historically large wildfires in the U.S. (Xu et al., 2020) and the increasing recognition of the potential for aerosol transmission of COVID-19 in poorly ventilated indoor environments (CDC, 2020), there has been an unprecedented level of interest and investment in indoor air cleaning technologies.

Here we report on controlled test chamber measurements conducted at the Illinois Institute of Technology to measure the pollutant removal efficacy of an Intellipure Compact Air Purifier. The product uses a combination of adsorption filter (for gases) and a proprietary/patented Disinfecting Filtration System (DFS) technology (for biological and non-biological particles).[1] Pollutant removal efficacy measurements included clean air delivery rate (CADR) characterizations for particulate matter ranging from 0.01 to 10+ µm in diameter following injection of incense and dust as well as the CADR for ozone (O_3) that was generated as a byproduct of incense burning. Ion concentrations were also measured inside the chamber to determine if the DFS technology functions as an ionizer.

Measurement Description

Tests were conducted in a large aluminum environmental chamber on the main campus of Illinois Institute of Technology in Chicago, IL (interior volume of 1296 ft^3) on August 3-5, 2021. The chamber is served by a recirculating air handling unit connected via a flexible aluminum duct, capable of recirculating between ~150 and ~200 cfm. Surrounding laboratory air enters unfiltered via infiltration through the chamber, air handler, and ductwork, typically around 1.9-2.0 air changes per hour (ACH) with the surrounding laboratory. A mixing fan was operated in the chamber to achieve reasonably well mixed conditions.

Pollutant Removal Efficacy Testing

Pollutant removal efficacy testing involved measuring the CADR for each air cleaner using a pollutant injection and decay method (Offermann et al., 1985; MacIntosh et al., 2008; US EPA, 2018). The CADR is a measure of how much pollutant-free air an air cleaner provides, reported in units of airflow

[1] https://www.intellipure.com/product/intellipure-compact/

rate (e.g., cubic feet per minute, or cfm). The CADR is traditionally measured for particulate matter but can also be measured for other types of airborne pollutants (Howard-Reed et al., 2008). Three particle size ranges are commonly tested in the widely used ANSI/AHAM AC-1 Test Standard, *Method for Measuring the Performance of Portable Household Electric Room Air Cleaners*: tobacco smoke (0.09-1 µm), dust (0.5-3 µm), and pollen (5-10 µm).

Pollutant injection was achieved by burning incense to generate particles primarily in the 'smoke' and 'dust' size ranges and shaking a vacuum cleaner bag filled with vacuumed dust to generate particles primarily in the 'pollen' size range (Stephens and Siegel, 2012). Burning incense also generates numerous gaseous pollutants (e.g., carbonyls, carbon monoxide, nitrogen oxides, and VOCs (Lee and Wang, 2004)) that may be used to estimate CADR for the measured gas-phase pollutants. Ozone was also detected as a product of incense burning, likely due to reactions between NO_x and VOCs (Hsu et al., 2019). Therefore, gas-phase CADR measurements also included O_3, as NO_x did not achieve high enough peaks and decays to solve for loss rates and the TVOC monitor failed to log data during this test.

Testing was first conducted with the air cleaner turned on immediately after pollutant injection completed. This allowed for estimating the decay rate of pollutants with the air cleaner turned on, which includes losses due to the 'natural' (i.e., background) decay due to deposition to surfaces, ventilation/infiltration, etc., *plus* the effect of the air cleaner operating. After pollutant concentrations (C_t) mixed and then decayed from the initial mixed peak (C_0) towards background levels in the chamber (C_{bg}), the air cleaner was turned off to reach a new chamber background (C_{bg}), and then pollutant injection was repeated and pollutant concentrations were allowed to decay with the air cleaner turned off to characterize only the 'natural' (i.e., background) decay rate.

A linear regression is used to estimate pollutant loss rates (K) under air cleaner on (K_{ac}) and off (K_{nat}) conditions:

$$- ln \frac{C_{in,t} - C_{bg}}{C_{in,t=0} - C_{bg}} = K \times t$$

The CADR is calculated as the difference between the two loss rates multiplied by the interior chamber volume:

CADR = V×(K_{ac} - K_{nat})

Where: V = volume of the test chamber (ft^3)
K_{ac} = total decay rate with air cleaner on (1/min)
K_{nat} = natural decay rate with air cleaner off (1/min)
t = time from the beginning of the decay period (min)

Measurement Equipment Used

1. TSI NanoScan SMPS 3910 for ultrafine particle number concentrations
2. TSI OPS 3330 and MetOne GT-256S OPC for 0.3-10+ µm particle number concentrations
3. Aeroqual Portable Handheld Air Quality Monitor for TVOC concentrations
4. 2B Technologies Models 211 and 405 for ozone and NO_x concentrations, respectively
5. Extech SD800 CO_2 monitors to assess air change rates
6. AlphaLab Air Ion Counter

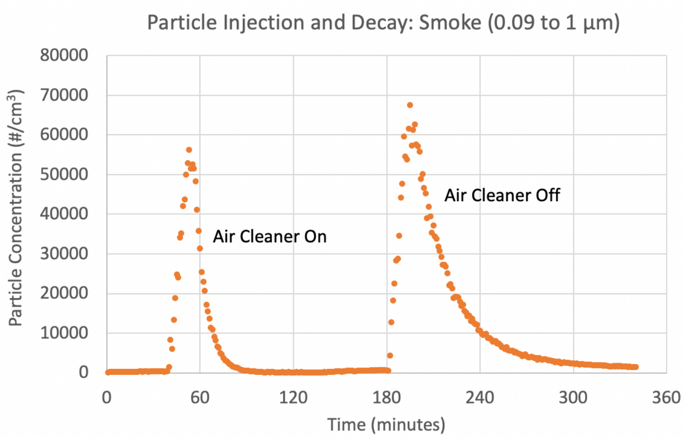
Photos of the Chamber and Instrumentation

The air cleaner (stand-alone option, i.e., non-wall mount) was placed on a table in the chamber and tested one time with the fan speed on the highest (turbo) setting and with the DFS function on (which is on by default, presumably engaging the electric grid portion of the DFS technology).

Figure 1. Inside chamber set up for the air cleaner CADR tests

Example Test Data

An example of resulting time-series test data is shown below for (i) particles in the 'smoke' size range during injection and decay measurements and (ii) negative ion concentrations during a separate approximately 2-hour period without pollutant injection (incense injection alters ion concentrations). Negative ion concentrations increased from an average of ~200 ions/cm^3 with the air cleaner off to ~600 ions/cm^3 with the air cleaner on, decaying again towards <200 when the air cleaner was again switched off an hour later.



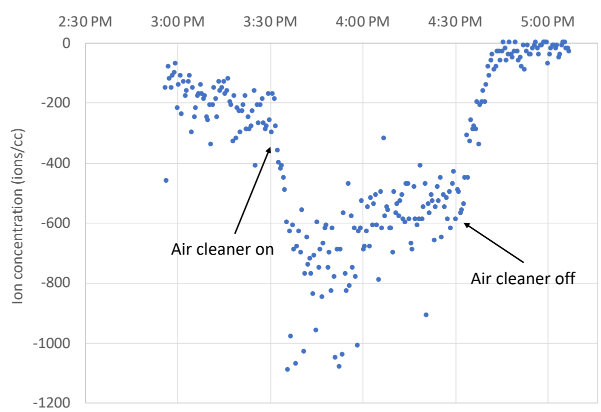


Figure 2. Example time-series test data from 'smoke' size particle injection and decay and ion concentrations measured during a separate period without particle injection

Pollutant Loss Rate Estimates

Resulting estimates of particle loss rate estimates during air cleaner on and off conditions for particles in each of the three particle size ranges are shown in Figure 3. The SMPS and OPS data were used for the 'smoke' size range and the MetOne data were used for 'dust' and 'pollen' size ranges. Figure 4 shows resulting O_3 loss rates during air cleaner on and off conditions.

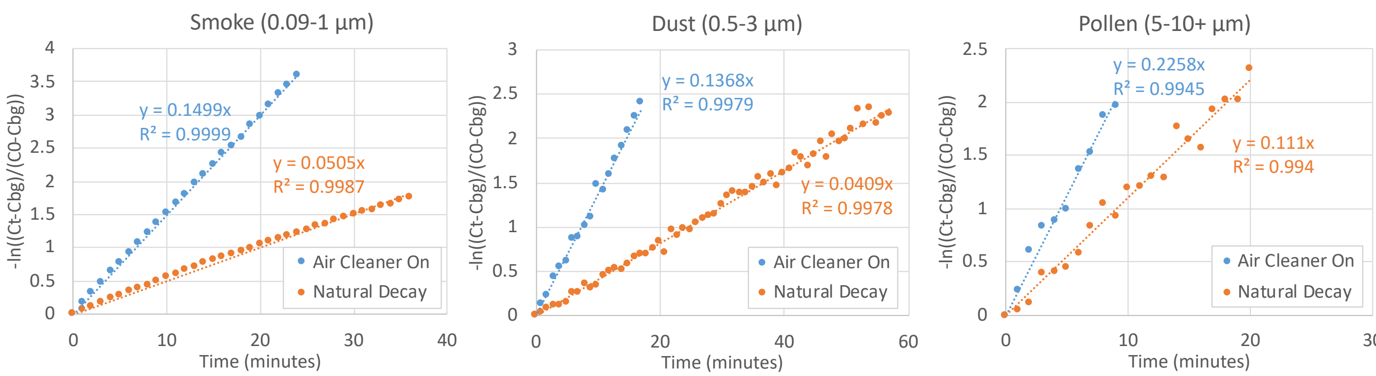


Figure 3. Estimated loss rate constants for the three particle size ranges

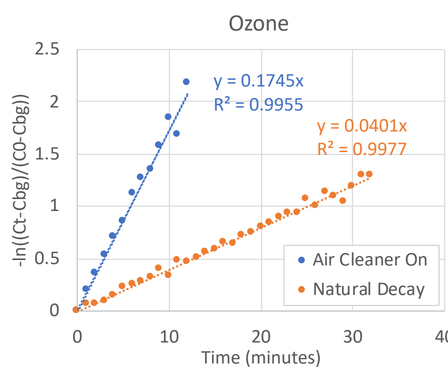


Figure 4. Estimated loss rate constants for ozone

Summary of Results

Table 1 shows results from CADR tests for the smoke (0.09-1 µm), dust (0.5-3 µm), and pollen (5-10+ µm) size ranges, which were estimated to be 129 cfm, 124 cfm, and 149 cfm, respectively. The CADR for O_3 was estimated to be 174 cfm. (Note that increased air speeds in the chamber with the air cleaner on versus off also contribute to increased loss rates in addition to the VOC filter inside the device (Kunkel et al., 2010), which means the actual CADR attributable to the air cleaner alone is lower than 174 cfm). There were no increases in NO_x or O_3 concentrations observed during air cleaner operation. There was an increase in negative ion concentrations from ~200 ions/cm^3 to ~600 ions/cm^3 during air cleaner operation.

Table 1. CADR test results for four particle size ranges

Metric	K_{ac} (1/min)	K_{nat} (1/min)	CADR (cfm)
Smoke (0.09-1 µm)	0.1499	0.0505	**129**
Dust (0.5-3 µm)	0.1368	0.0409	**124**
Pollen (5-10+ µm)	0.2258	0.1110	**149**
Ozone (O_3)	0.1745	0.0401	**174**

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