Portable Air Cleaner Test Report

WINIX 5500-2 Portable Air Purifier: Impact of Ionizer

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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 importance of aerosol transmission of COVID-19 in 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 a WINIX 5500-2 portable air purifier. The product uses four stages of technologies: (1) pre-filter, (2) washable carbon filter, (3) HEPA filter, and (4) PlasmaWave® hydroxyl generator.[1] The product has been tested by AHAM to have a clean air delivery rate (CADR) of 243, 232, and 246 cfm for dust, smoke, and pollen particle size ranges in the test and to meet AHAM ozone (O_3) emission limits of less than 50 ppb in a test chamber.[2]

Measurements included CADR characterizations for particulate matter ranging from 0.01 to 10+ μm in diameter following injection of incense and dust, both with and without the ionizer disabled, as well as measurements of negative ion concentrations during normal operation in the chamber (i.e., without pollutant injection) and with the ionizer disabled.

Measurement Description

Tests were conducted in a large aluminum environmental chamber (interior volume of 1296 ft^3). The unit was first tested in January 2021 with the chamber operating in a single-pass-through configuration in which surrounding laboratory air was supplied to the chamber without recirculation.[3] The unit was tested again in October 2021 with the chamber operating in recirculating mode, where 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 small mixing fan was operated in the chamber to

[1] https://www.winixamerica.com/wp-content/uploads/2021/10/5500-2_User-Manual_210930.pdf
[2] https://www.ahamdir.com/room-air-cleaners/
[3] http://built-envi.com/wp-content/uploads/IIT-CADR-Testing-February-2021.pdf

encouraging mixing. These repeated measurements were conducted to ensure that results from tests with the ionizer enabled and disabled were directly comparable, i.e., conducted at the same chamber test conditions. This report summarizes the tests from October 2021.

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 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). Only loss rate data for particulate matter are analyzed here.

Testing was first conducted with the air cleaner turned on either during or 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:

$$\text{CADR} = V \times (K_{ac} - K_{nat})$$

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

Test Conditions

The air cleaner was placed on a table in the chamber and tested on the highest fan speed setting. During these October 2021 tests, the unit was tested during three conditions: (1) during normal operation (with all air cleaning technologies engaged) without pollutant injection to measure resulting ion concentrations (in the event that the PlasmaWave® technology generates ions); (2) during normal operation (with all air cleaning technologies engaged) with pollutant injection and decay to characterize the CADR for particulate matter; and (3) during operation with the PlasmaWave® technology disabled and with pollutant injection and decay to characterize the CADR for particulate matter with this function switched off (see Figure 1).

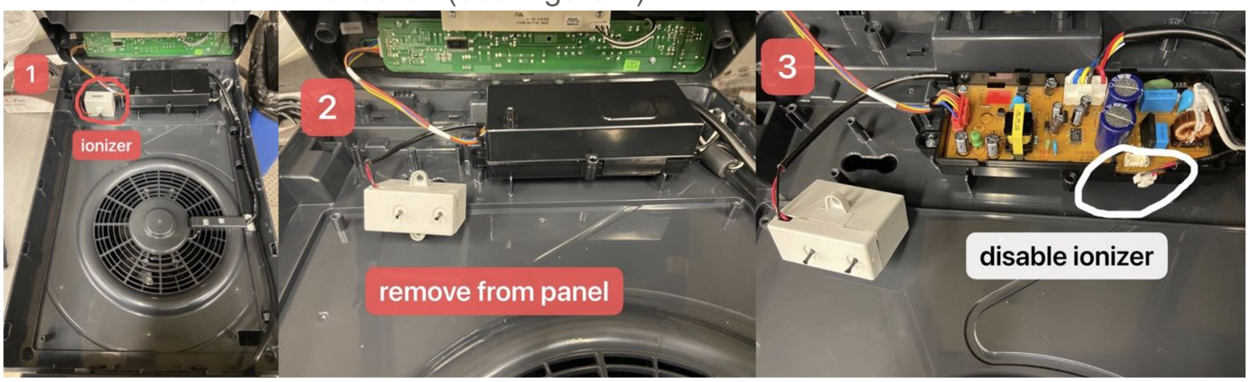

Figure 1. Steps taken to disable ionizer on the unit

Example Test Data: Particle Injection and Decay

An example of resulting time-series test data is shown below for particles in the 'smoke' size range during injection and decay measurements (i) during normal operation (October 14, 2021) and (ii) during operation with the PlasmaWave® technology disabled (October 10, 2021).

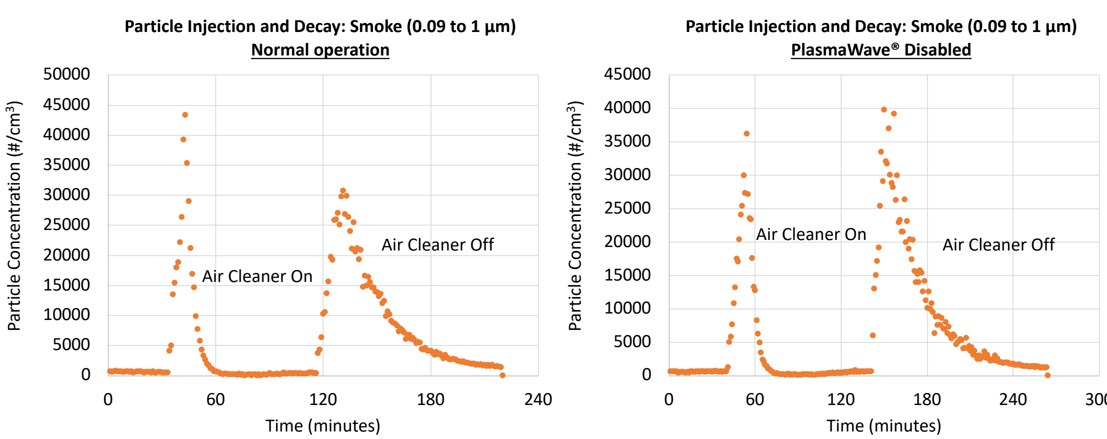

Figure 2. Example time-series test data from 'smoke' size particle injection and decay tests

Example Test Data: Ion Concentrations

Figure 3 shows a time-series profile of negative ion concentrations measured with the unit operating in the test chamber without any pollutant injection. The air cleaner remained off from 19:00 to 19:40. At 19:41, the air cleaner with the PlasmaWave® technology function enabled was switched on to its highest fan speed setting. The unit was left on for approximately one hour and then switched off at 20:39. Negative ion concentrations increased rapidly upon switching on the unit, increasing to an average of ~48,000 ions/cm^3 during operation.

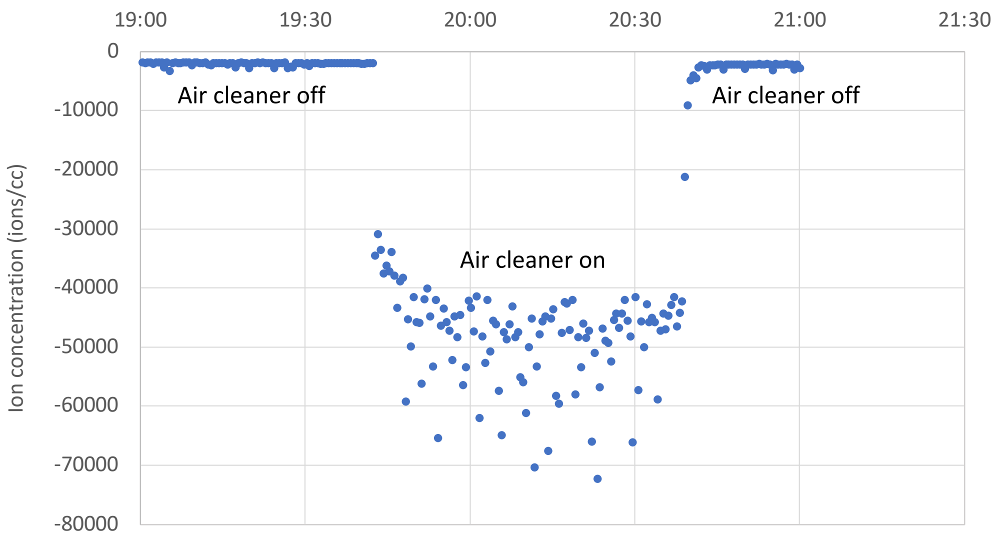

Figure 3. Time-series ion concentrations measured in the chamber during normal operation (no pollutant injection) with the PlasmaWave® technology enabled

Example Test Data: Pollutant Loss Rate Estimates

Examples of resulting estimates of particle loss rates during air cleaner on and off conditions, with and without the ionizer enabled, for particles in the 'smoke' size range are shown in Figure 4.

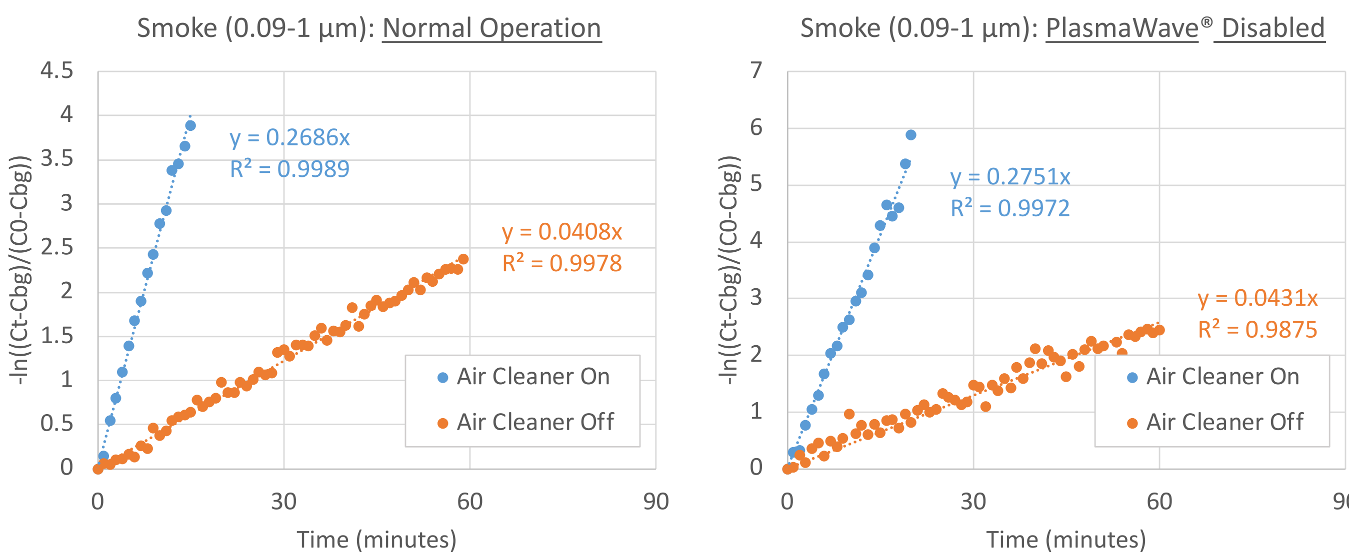

Figure 4. Example of estimated loss rate constants

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, both during normal operation (PlasmaWave® enabled) and with the PlasmaWave® function disabled.

Table 1. CADR test results for three particle size ranges

Particle Metric	Normal Operation October 14, 2021			PlasmaWave® Disabled October 10, 2021			% Difference in CADR
	K_{ac} (1/min)	K_{nat} (1/min)	CADR (cfm)	K_{ac} (1/min)	K_{nat} (1/min)	CADR (cfm)	
Smoke (0.09-1 µm)	0.2686	0.0388	298	0.2751	0.0431	301	**+1%**
Dust (0.5-3 µm)	0.2523	0.0445	269	0.2569	0.0385	283	**+5%**
Pollen (5-10+ µm)	0.3401	0.125	279	0.292	0.1159	228	**-18%**

The CADR for smoke, dust, and pollen particle size ranges during normal operation (with the PlasmaWave® technology enabled), tested with the chamber in recirculation mode, were estimated to be 298, 269, and 279 CFM, respectively. These CADR values are 11% to 28% higher than values reported in AHAM certified testing, and 10-14% higher than values measured during initial tests conducted in January 2021 with the chamber operating in single-pass-through mode.

The CADR for smoke, dust, and pollen particle size ranges during operation with the PlasmaWave® technology disabled were estimated to be 301, 283, and 228 CFM, respectively. The smoke and dust CADRs were within 5% of each other with or without the PlasmaWave® technology enabled, suggesting the function does not meaningfully affect CADR values for these size ranges. The CADR in the pollen size range was ~18% lower with the PlasmaWave® technology disabled compared to that measured with the PlasmaWave® technology enabled.

Based on these results, we estimate that for particles in the smoke and dust size range, the PlasmaWave® technology does not affect the device CADR, but the technology does appear to contribute to the total CADR for particles in the pollen size range. Moreover, the PlasmaWave® technology appears to function as an ion generator, as measured. Given the potential for ionization and other additive oxidizing technologies to initiate indoor chemical reactions (Collins and Farmer, 2021; Joo et al., 2021; Kim et al., 2017; Ye et al., 2021; Zeng et al., 2021), further testing should also characterize the impact of this device on gas-phase organic compounds (e.g., VOCs, aldehydes, etc.).

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