Performance of Air Cleaners: A New Test Method and Results

Zhenlei Liu[1], Eloise Parry-Nweye[2], Xin Guo[1], Yousr Dhaouadi[2], Xuezheng Wang[1], Jialei Shen[1], Beverly Guo[1], Moises Ramirez[3], Bhavesh Gupta[3], Dacheng Ren[2], Bing Dong[1], Jianshun Zhang[1]

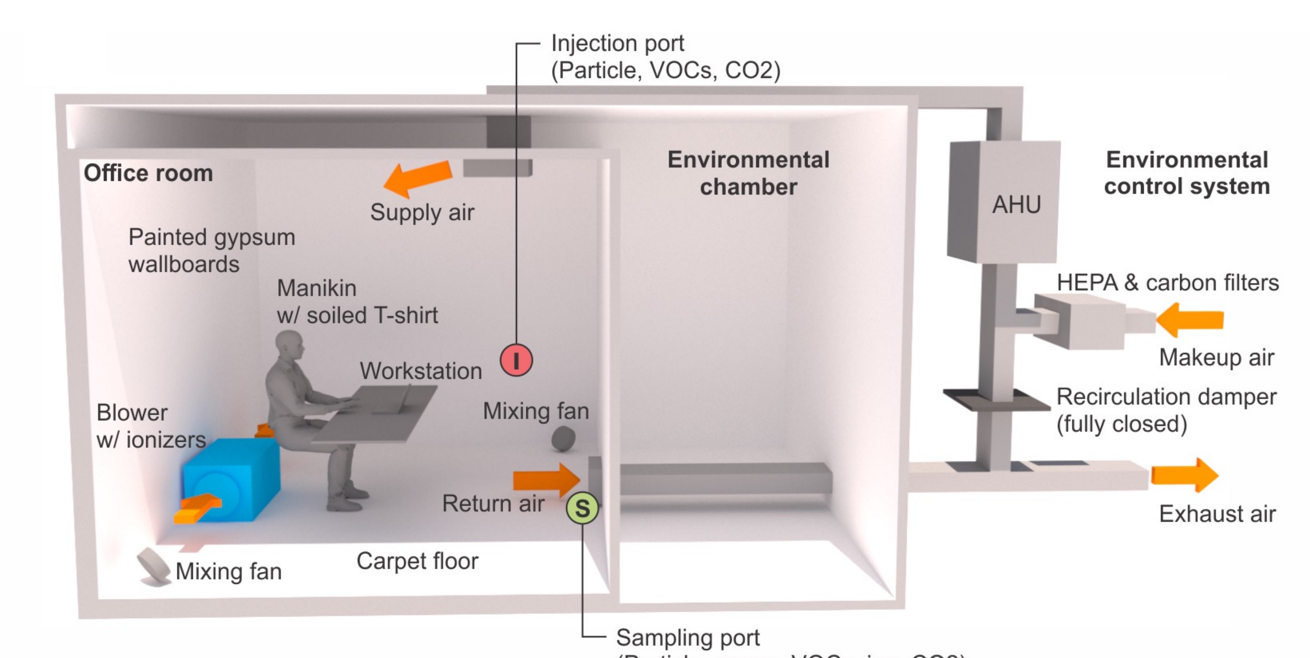
[1] Department of Mechanical and Aerospace Engineering, Syracuse University, USA
[2] Department of Biomedical and Chemical Engineering, Syracuse University, USA
[3] Honeywell International Inc., Atlanta, Georgia, USA

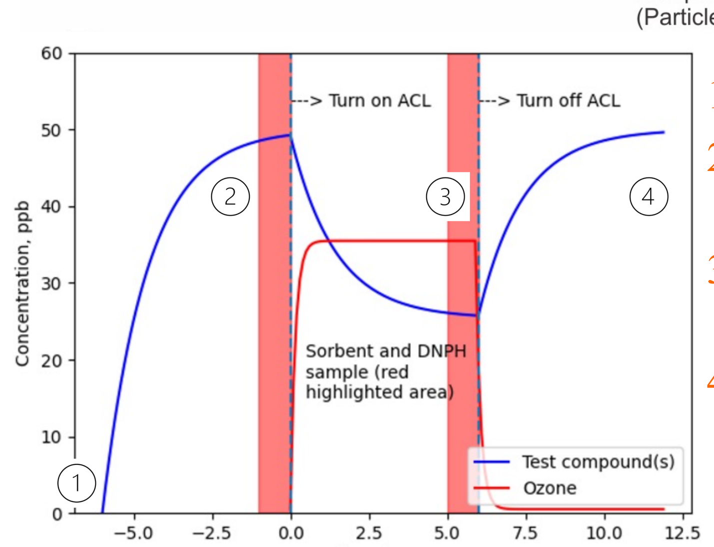
Introduction

The classical pull-down method for testing air cleaner performance requires high initial challenge concentrations of pollutants and is performed during a transient pollutant concentration period. This does not reflect the device's usage condition where concentrations are significantly lower and remain relatively constant under a constant ventilation rate. Previous tests are mostly conducted under empty chamber with a single type of challenge pollutants, while a different type of pollutants typically co-exists in the real environment. This study proposes a comprehensive approach to test various types of cleaners and pollutants under the same realistic usage condition. A test procedure has been developed involving constant injections of target pollutants and comparison of the measured concentrations with and without the operation of the device under a condition with realistic ventilation rate, typical interior surfaces, furnishing, and simulated occupancy. Results show that the procedure can effectively measure the performance of different types of air cleaners for removing the target pollutants.

Chamber Test Method

All contaminants were injected into the test room. The particle (PM2.5 and PM10) concentration was monitored real time. VOC and virus surrogate were collected at two steady states before and after turning on the air cleaner.





1) Background condition monitoring
2) Steady state concentration measurements with air cleaner off
3) Steady state concentration measurements with air cleaner on
4) Residual by-products detection

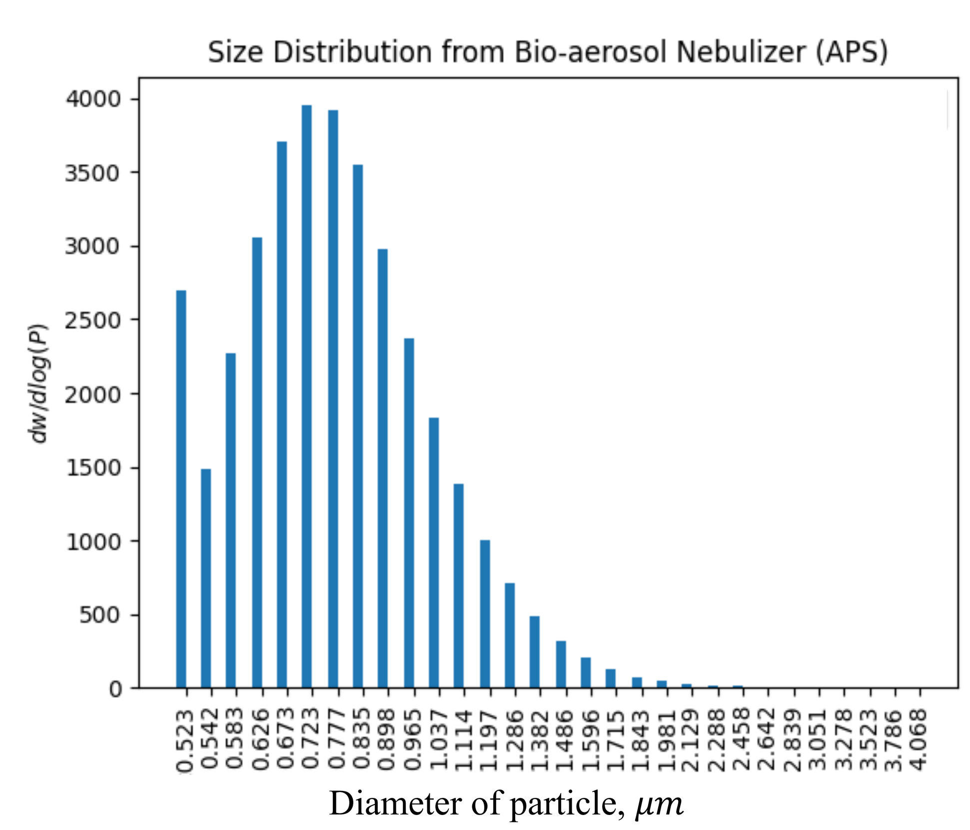
Selection of Air Cleaners

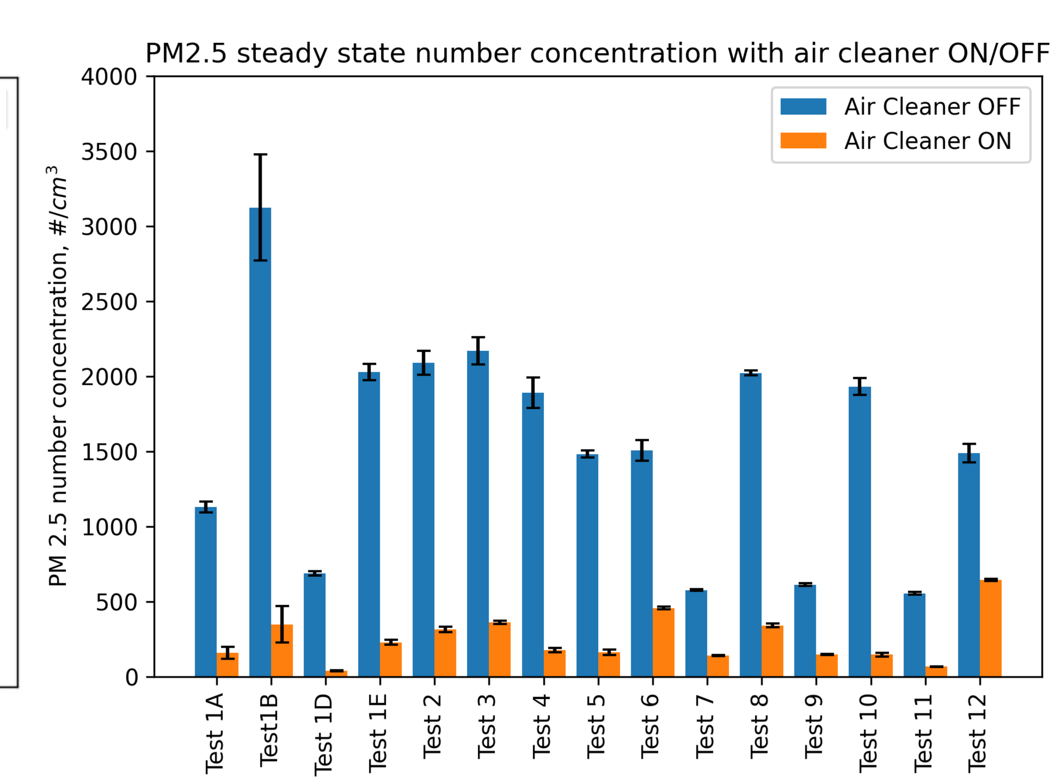
Air cleaner	HEPA filter	Electrostatic	Ionization/ Plasma	Physical adsorption	Chemical adsorption	UVPCO
Cleaner 1		☑		☑		
Cleaner 2	☑			☑		
Cleaner 3	☑		☑	☑		
Cleaner 4		☑				
Cleaner 5		☑				
Cleaner 6				☑		☑
Cleaner 7	☑			☑		
Cleaner 8	☑		☑	☑		
Cleaner 9	☑			☑		
Cleaner 10	☑			☑	☑	
Cleaner 11	☑		☑	☑	☑	☑
Cleaner 12	☑					☑

Chamber Test Results of PM2.5

VOCs (formaldehyde and toluene), particles (PM2.5 and PM10), and virus surrogate (*Phi6*) were injected into the test room as selected contaminates.

NaCl water and virus phage buffer were used to generate the non-virus particle and the virus-laden particle, respectively. The size distribution and number concentration in the air of particles are shown as below.

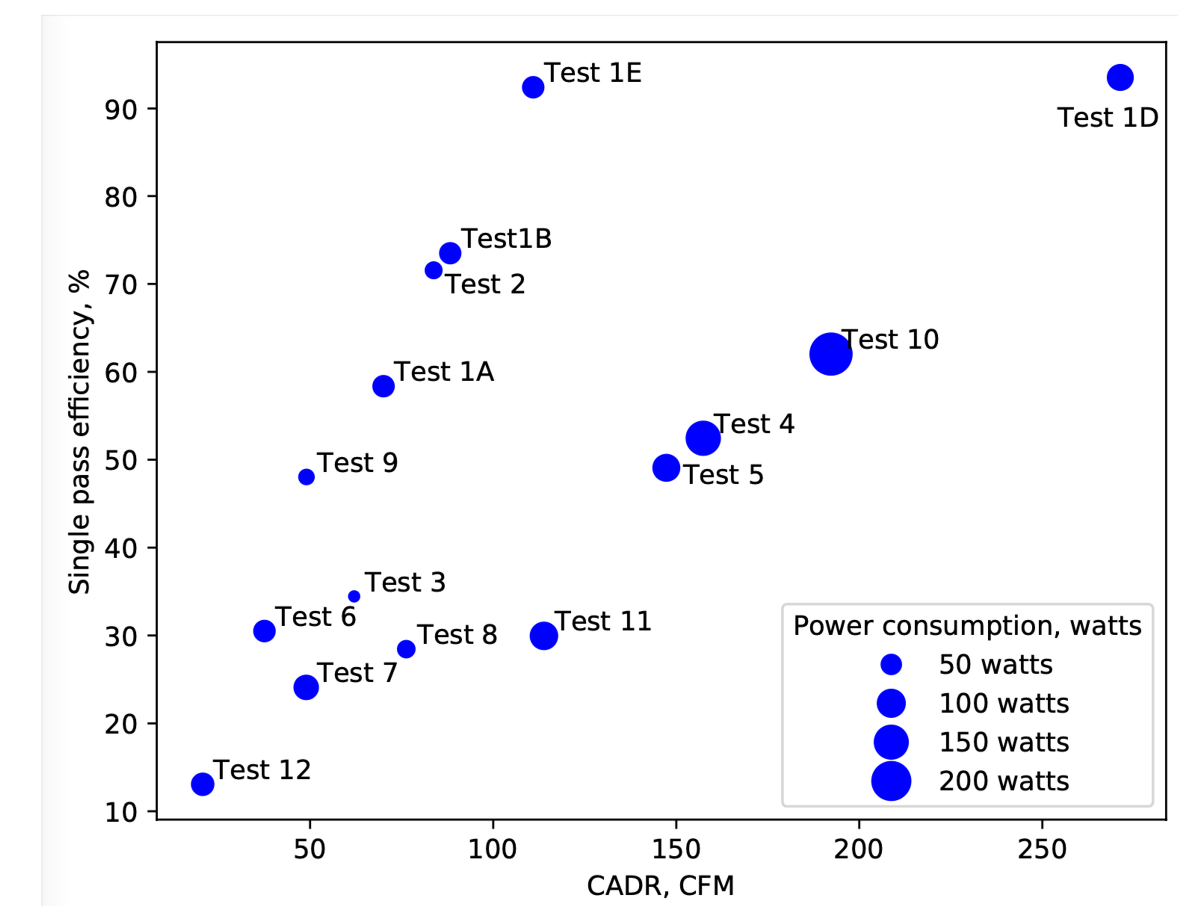




The median value of the particle size < 1 μm for both non-virus particle and virus-laden particle. The challenge particle concentration of the air cleaners are ~ 500 $\#/cm^3$ for the non-virus particle and ~ 2000 $\#/cm^3$ for the virus-laden particle, which represent a dirty condition with the worst-case ventilation scenario.

Performance of PM2.5 Removal

The key parameters to evaluate the performance of the air cleaner are 1) clean air delivery rate (CADR); 2) concentration reduction factor (CRF); 3) single pass efficiency (SPE); 4) power consumption.



Considering the 4 parameters, Test 1D has the best performance with reasonable power consumption. If use the required ventilation rate in ASHRAE 62.1 as a reference, all the tested air cleaners can provide at least 2 times of the required cleaner air for PM2.5 removal.

Summary and Future Work

A novel and comprehensive test method has been developed for the measurement of the performance of both portable and in-duct air cleaner. A reference room that representing a realistic indoor environment has been built in the BEESL Lab's IEQ chamber with well-controlled environment. The chamber tests provided well-controlled conditions for testing the effects of temperature, humidity, and outdoor air. Contaminants were constantly injected into the test room to simulate a stable emission source and the contaminants' concentrations were measured at the exhaust air to reflect the average pollutant level in the room. By comparing the contaminants' concentration with and without the operation of the air cleaner, we can evaluate the performance of the air cleaners under a realistic condition.

The results from the chamber tests have shown a good repeatability. The ideal air cleaner will provide a high CADR and a high single pass efficiency to reduce the energy consumption and noise. More studies are needed to develop a criteria of virus infection risk control based on the existing data and provide guidance on improving air cleaner design.