IMPECCABLE AIR

Efficacy of the Impeccable Air Return Grille Filters in Reducing VOCs and Particulates

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I. Abstract

FDA Compliance: This study was conducted in compliance with FDA Good Laboratory Practices (GLP) as defined in 21 CFR, Part 58.

Purpose: This study's primary objective was to evaluate the Impeccable Air Return Grille Filter's effectiveness in reducing Volatile Organic Compounds (VOCs) and capturing particulate matter within a simulated HVAC duct system to improve indoor air quality (IAQ).

Background: This research centers around the evaluation of the Impeccable Air Return Grille Filter. These filters are proposed as an addon to existing HVAC systems through placement within the return air vent, thereby harnessing the mechanical air circulation to contribute actively to air quality improvement. The choice of criteria for evaluation—Volatile Organic Compounds (VOCs) reduction and particulate capture & reduction—aligns with established methods of assessing the efficiency of similar air quality enhancement technologies.

Methods: Filter performance was assessed in a controlled environment using a custom duct system with integrated filters. The study involved two phases: first, VOC reduction (formaldehyde, limonene) was monitored using an FTIR gas analyzer; second, particulate capture efficiency (Arizona Road Dust aerosol) was measured with an Aerodynamic Particle Sizer. Control trials without the filter were conducted for both VOCs and particulates to determine net reduction attributable to the device by accounting for natural decay.

Results: The Impeccable Air Return Vent Filter demonstrated efficacy in reducing Volatile Organic Compounds (VOCs) and particulate matter. After 60 minutes the test trial with the filter yielded a 22.13% reduction in formaldehyde concentration compared to a 11.46% reduction in the control, and the test trial with the filter yielded a 38.97% reduction in limonene concentration compared to a 22.92% reduction seen in the control trial. Significant particulate matter removal was achieved across all tested sizes. After 60 minutes, net reductions reached 89.94% for ultra-fine (<0.543µm), 91.00% for fine (0.5- 0.8µm), 95.77% for alveolar (0.8-5µm), and over 99.99% for coarse (5-20µm) particles when compared to control decay (Data from Table 2). Particulate CADR values were notably higher than VOC CADR, ranging from 22.52 CFM (ultra-fine) to 108.91 CFM (coarse), indicating substantial particle removal capability under the test conditions (Data from Table 2 image_581bb9.png). These results quantify the filter's contribution to improving key indoor air quality metrics.

Conclusions: The Impeccable Air Return Vent Filter demonstrated effective reduction of tested VOCs and significant removal of particulate matter across all sizes under laboratory conditions. Calculated CADR values quantify this performance. Results indicate the filter contributes positively to improving measured indoor air quality metrics when integrated into a simulated HVAC system.

II. Introduction

This report covers testing that is aimed at evaluating the efficacy of the Impeccable Air Return Vent Filters when integrated into an HVAC system. These filters are designed to harness the air circulation provided by a house or business's HVAC, ultimately seeking to augment the air quality of indoor settings.

The central question addressed in this study is whether these filters can effectively capture and reduce VOCs and particles. To test the filters, we employed a controlled testing environment, focusing on the ability of the filters to alleviate VOCs and their competence in capturing aerosolized particulate matter.

Through a series of trials, the filters' performance was examined, measuring their impact on both. VOC concentration reduction and particle capture efficiency relative to control trials.

III. Study Overview

This study was structured into two phases to evaluate the filters' performance. The first phase involved testing the filters' efficacy in reducing VOC concentrations, utilizing two distinct VOCs—formaldehyde and limonene—as challenges. The tests were conducted with a single filter configuration and fan speed, each trial and control lasting 1 hour, and monitored using a VOC gas analyzer.

In the second phase, the filters' ability to capture particulate matter was evaluated using aerosols of varying sizes, generated through aerosolized "Arizona Road Dust." The efficiency of particulate capture was monitored using an Aerodynamic Particle Sizer. Control trials were conducted with the blower at the same speed as the filter trials with no filters installed in the system.

Figure 1 below provides an overview for the VOC and Particle testing of the Impeccable Air Filter:

Impeccable Air Particle Testing Matrix

Trial	Filter	Challenge Particulates	Challenge Concentration (#/cm^3)	Blower Speed (ft/min)	Trial Time (min)	Sampling Equipment
Control	No Filter	Arizona Road Dust (0 - 20µm Size)	2000 - 3000	400 ft/min	60	TSI Aerodynamic Particle Sizer (APS) 3321
Impeccable Air T1	Impeccable Air Return Vent Filter	Arizona Road Dust (0 - 20µm Size)	2000 - 3000	400 ft/min	60	TSI Aerodynamic Particle Sizer (APS) 3321
Impeccable Air T2	Impeccable Air Return Vent Filter	Arizona Road Dust (0 - 20µm Size)	2000 - 3000	400 ft/min	60	TSI Aerodynamic Particle Sizer (APS) 3321

Impeccable Air VOC Testing Matrix

Test ID	Filter	Challenge VOC	Challenge Concentration (ppb)	Blower Speed (ft/min)	Trial Time (min)	Instrumentation
Control	No Filter	Formaldehyde	4000 - 5000	400 ft/min	60	MAXiR FTIR Gas Analyzer
Impeccable Air	Impeccable Air Return Vent Filter	Formaldehyde	4000 - 5000	400 ft/min	60	MAXiR FTIR Gas Analyzer
Control	No Filter	Limonene	5000 - 6000	400 ft/min	60	MAXiR FTIR Gas Analyzer
Impeccable Air	Impeccable Air Return Vent Filter	Limonene	5000 - 6000	400 ft/min	60	MAXiR FTIR Gas Analyzer

Figure 1 - Test Matrices for VOC and Particle testing of the Impeccable Air Filter

VOC Selection: The VOCs chosen to test the device were chosen due to the prevalence of the chemicals in the environment daily and the potential for them to be harmful to people. Formaldehyde is an organic compound with the chemical formula CH2O. It is created spontaneously through the polymerizes of paraformaldehyde and occurs naturally through the degradation of many plastic materials. Formaldehyde can irritate the eyes and throat and can cause long-term effects on the nervous system. Limonene is a terpene often found in cleaning chemicals. In many people, terpenes can cause allergic reactions leading to runny noses, irritated eyes, and coughing.

IV. Results

Data Analysis: The data analysis for the VOC's and the particulate testing followed the same analysis technique. The data for the test trials and controls were plotted to show the natural decay over time and the decay over time with the test device in use. To calculate the net reduction achieved by the device the natural decay was subtracted from the gross reduction of the filter trials.

For the particulate testing this was done across multiple size ranges including the fine particle size range (0.3 – 0.83µm), the alveolar range (0.83 – 5.0µm) and the coarse range (5.0 – 20.0µm).

Using the reduction over time data the clean air delivery rate (CADR) of the test device used in the system was calculated. The calculation for the CADR entailed subtracting the slope of the control trial from the slope of the test trial to attain a net slope. Using the net slope and the trial length the equivalent air change rate was calculated. From the equivalent air change rate, the size of the chamber was factored into the calculation to yield a net CADR for the device trial.

VOC Results:

Overview

Two separate VOC's were introduced into the test chamber containing the Impeccable Air Return Vent test system. After introduction the VOC concentrations were monitored to quantify the reduction over time yielded during a trial with the filter in place and a control trial.

Formaldehyde Results

The testing with formaldehyde resulted in a quantifiable net reduction yielded by the Impeccable Air Return Vent Filter. After 60 minutes the test trial with the filter yielded a 22.13% reduction in formaldehyde concentration compared to a 11.46% reduction in the control. A graph showing the percent of formaldehyde remaining over time in the chamber for the test trial and control can be found below:

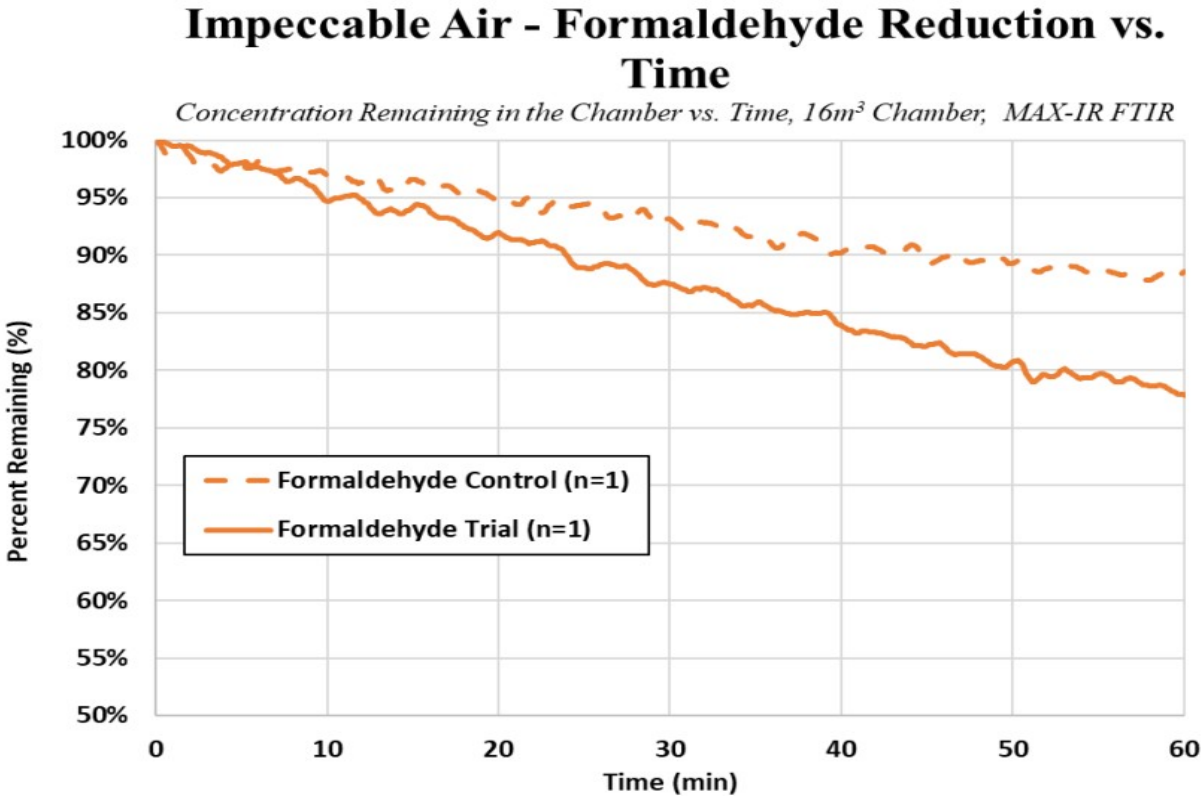


Figure 2 - Percent of Formaldehyde remaining over time for the control and Impeccable Air Trial

Limonene Results:

The testing with limonene resulted in even more net reduction yielded by the Impeccable Air Return Vent Filter than formaldehyde. A graph showing the percent of limonene remaining over time in the chamber for the test trial and control can be found below:

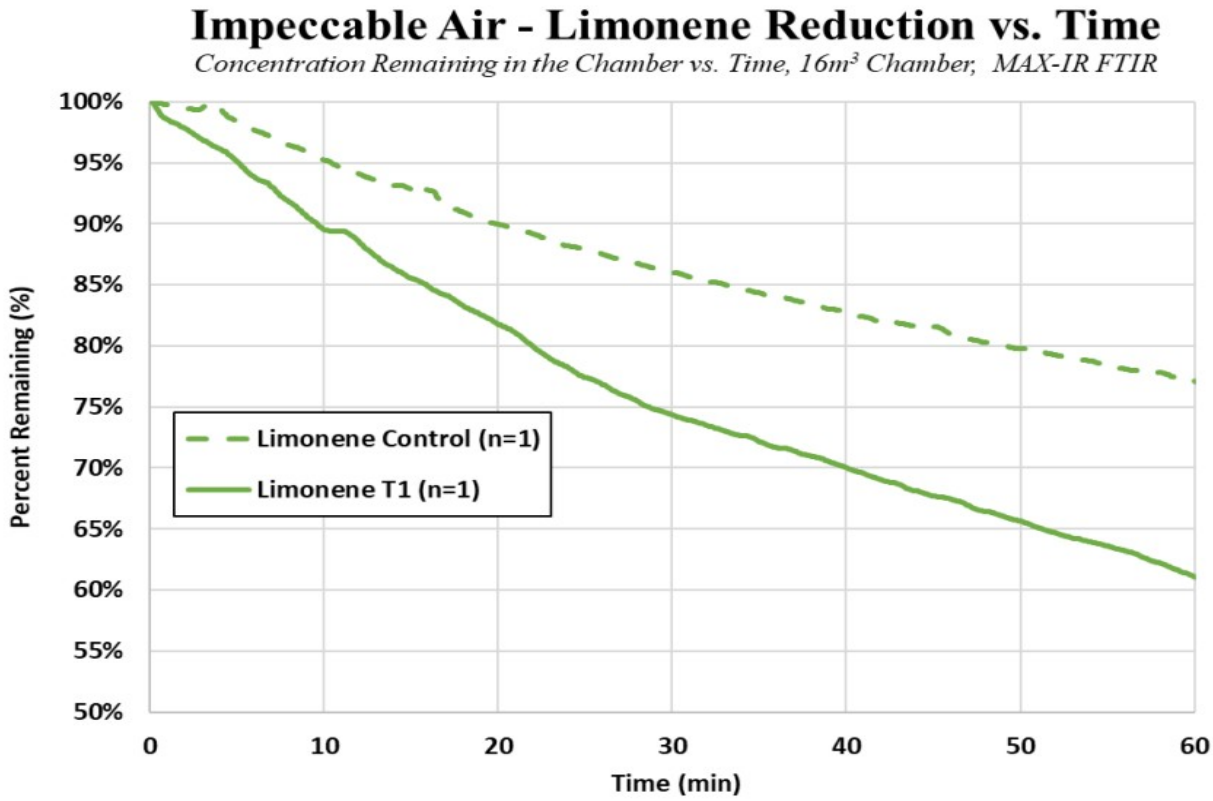


Figure 3 - Percent of Limonene remaining over time for the control and Impeccable Air Trial

After 60 minutes the test trial with the filter yielded a 38.97% reduction in limonene concentration compared to a 22.92% reduction seen in the control trial.

Summary of VOC results

The VOC results showed that the Impeccable Air Return Vent Filters had a positive impact on the reduction of concentration of Formaldehyde and Limonene over time when tested in the test chamber. When tested against Formaldehyde the device yielded a 22.13% percent reduction over time while the control yielded a 11.46% reduction over the same amount of time. Against the terpene Limonene the filter was even more effective. After 60 minutes the filter yielded a 0.21 log reduction compared to a 0.11 log reduction in the control trial for a net log reduction of 0.10. This data suggests that over time the filter would help treat a room contaminated with VOC's.

Particulate Testing Results:

Overview

Arizona road dust was aerosolized into the test chamber containing the test system with the Impeccable Air Return Vent System connected to one end and a blower on the other end. The chamber was sampled over time to characterize the reduction yielded by the filter while in operation. A control trial was conducted to assess the natural losses of particulate over time within the chamber.

Ultra-fine Particulate Results

Ultra-fine particles are defined as being under 0.5µm in size. When characterizing the device against these particles the data showed that the device yielded a noticeable net reduction when compared to the control trial. After 60 minutes the device averaged a 93.05% reduction in ultra-fine particles compared to a 30.95% reduction seen in the control trial. A graph depicting the results of the control and duplicate trials in the ultra-fine range can be found below:

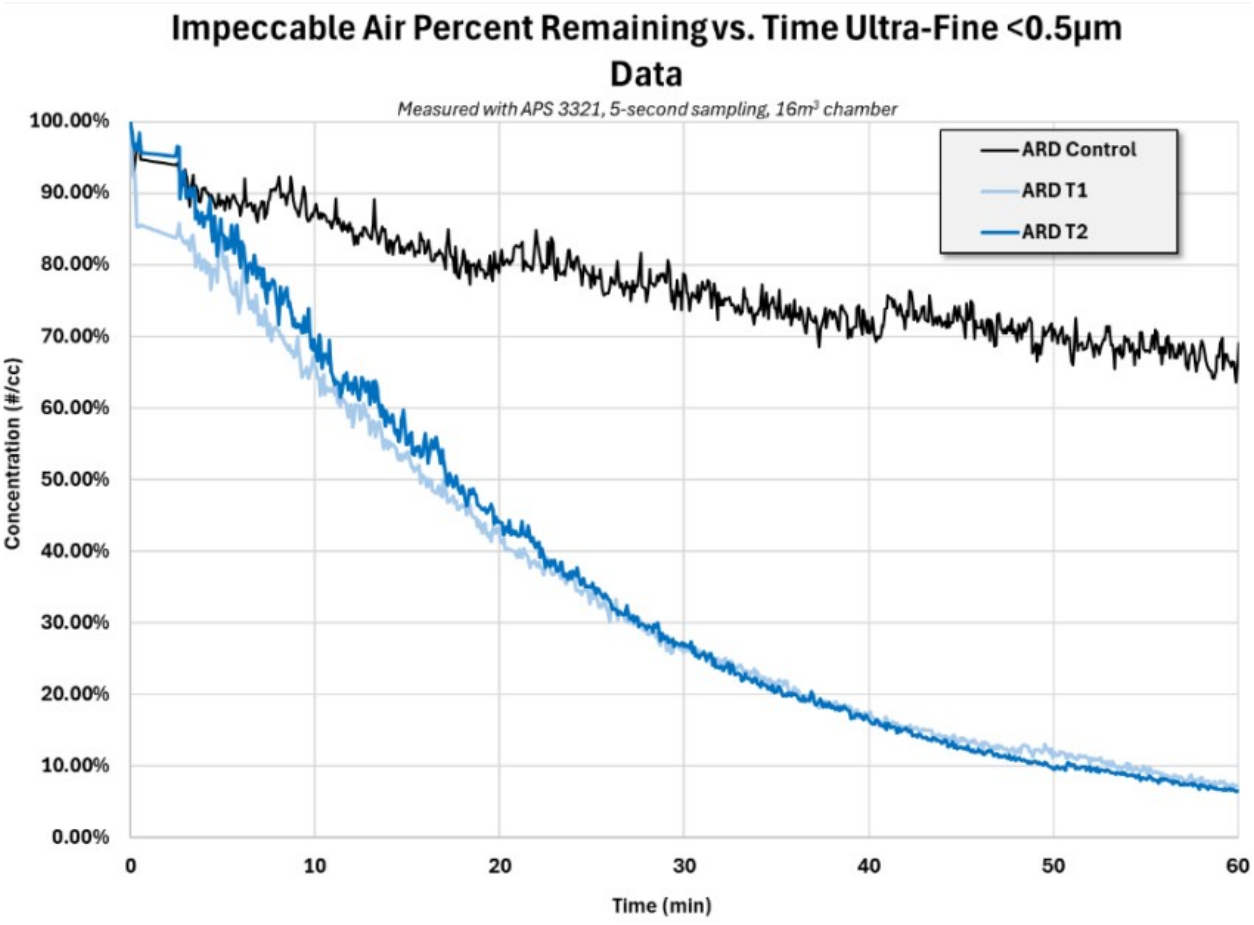


Figure 4 - Percent of particulate remaining airborne in the chamber in the ultra-fine particulate range over time

Fine Particulate Results

Fine particulate matter, ranging from 0.5 to 0.8µm, was also effectively reduced by the Impeccable Air filter system. Test trials showed an average reduction of 93.49% after 60 minutes, significantly higher than the 27.66% reduction observed in the control trial during the same period. This indicates substantial capture efficiency within this size range:

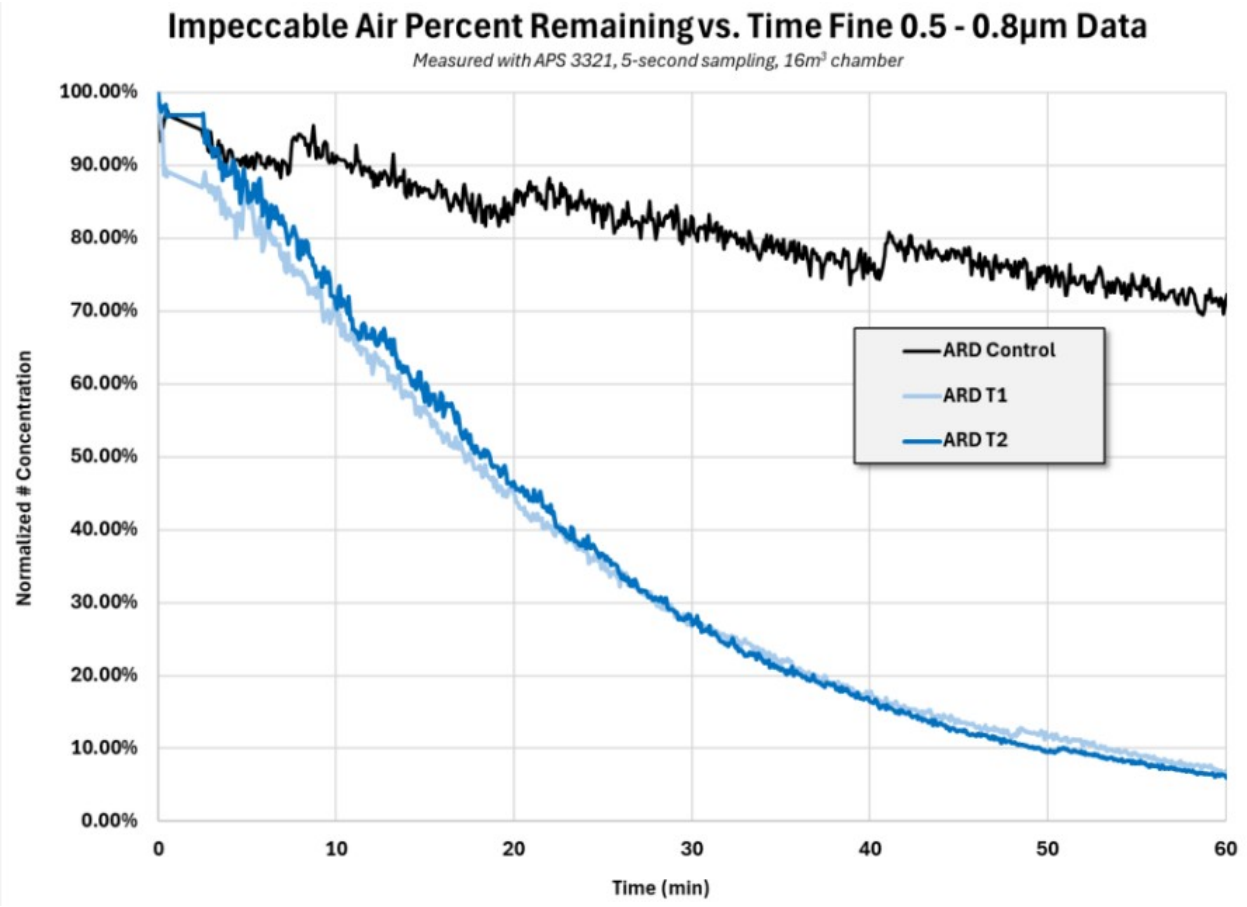


Figure 5 - Percent of particulate remaining airborne in the chamber in the fine particulate range over time

Alveolar Particulate Results

Particles in the alveolar range (0.8 – 5.0µm) showed high reduction rates. The average reduction across test trials reached 97.94% after 60 minutes, compared to 51.28% in the control. Figure 6 displays the normalized concentration decline for this particle size range:

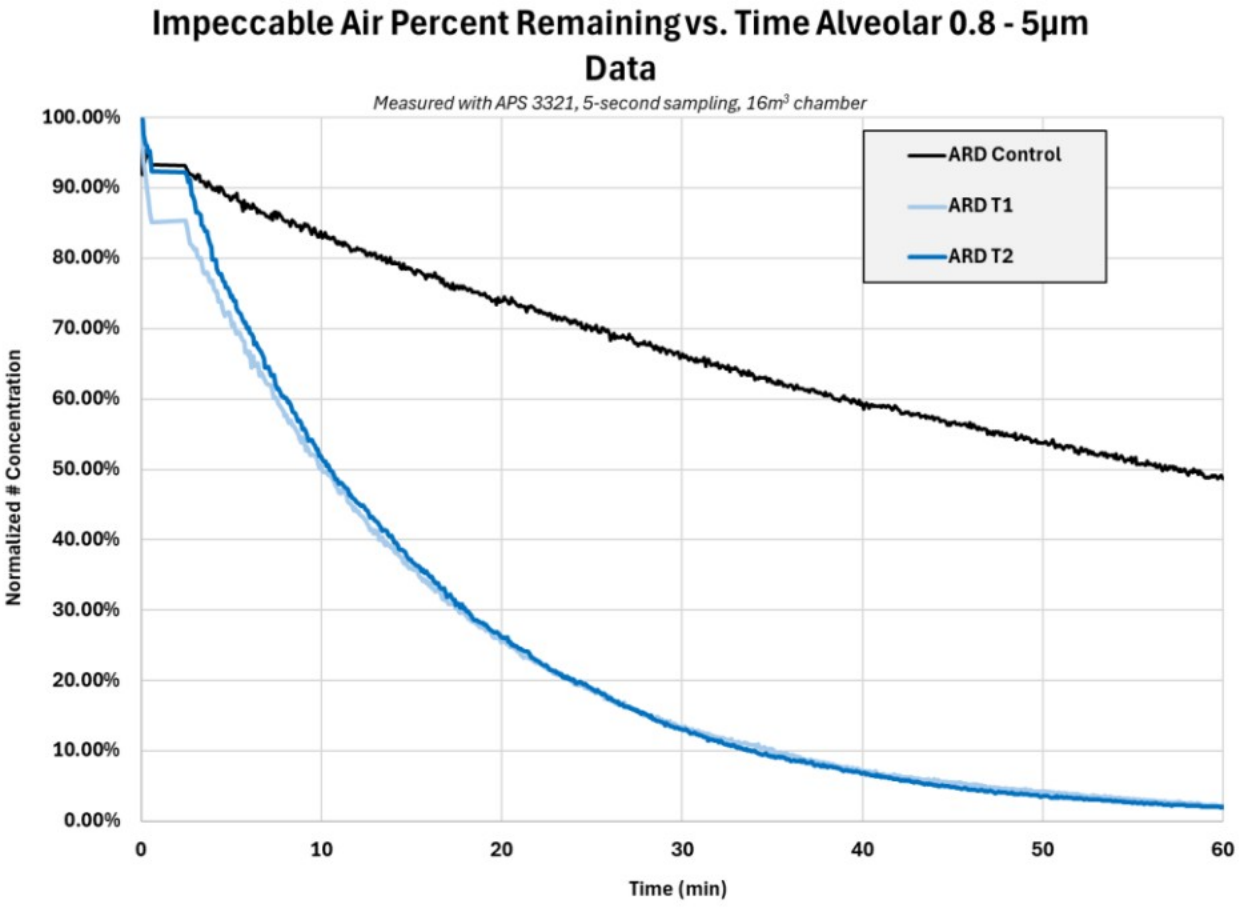


Figure 6 - Percent of particulate remaining airborne in the chamber in the alveolar range over time.

Coarse Particulate Results

The filter demonstrated very high efficacy against coarse particles (5.0 – 20.0µm). The average reduction over 60 minutes in test trials was 99.99993%. The rapid removal by the filter system is evident in Figure 7:

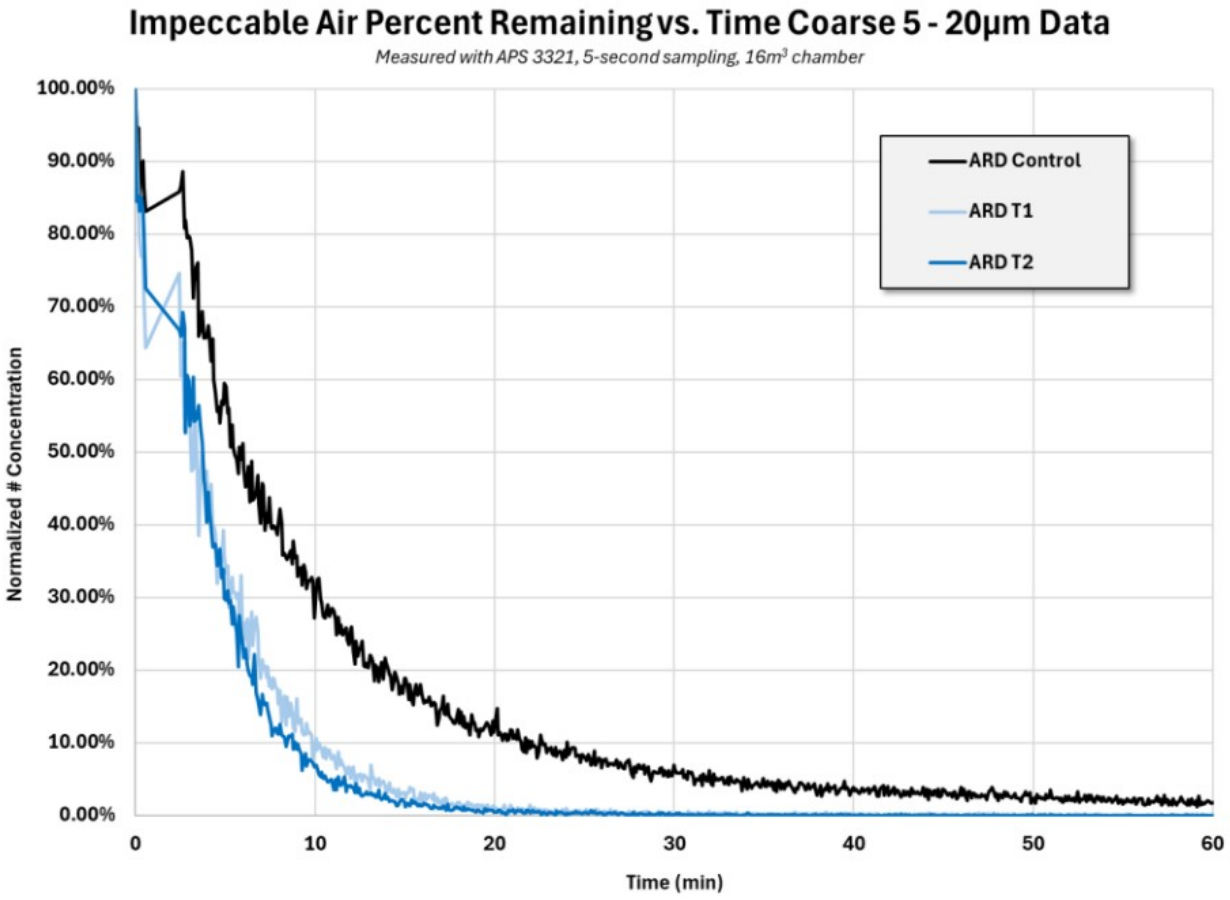


Figure 7 - Percent of particulate remaining airborne in the chamber in the coarse range over time.

Trial-by-trial particulate reduction results with average percent and log reductions by size:

Trial Reductions in Particulate Matter by Size Range

Trial	Reduction Type	Ultra Fine Particles (<0.5µm)	Fine Particles (0.5-0.8µm)	Alveolar Particles (0.8 - 5.0µm)	Coarse Particles (5.0 - 20.0µm)
Control	Percent Reduction	30.95%	27.66%	51.28%	90.43%
	LOG Reduction	-0.16	-0.14	-0.31	-1.46
Trial 1	Percent Reduction	92.71%	93.00%	97.87%	99.99986%
	LOG Reduction	-1.14	-1.15	-1.67	-5.85
Trial 2	Percent Reduction	93.39%	93.98%	98.01%	99.999996%
	LOG Reduction	-1.18	-1.22	-1.70	-7.35
Trial Average	**Percent Reduction**	**93.05%**	**93.49%**	**97.94%**	**99.99993%**
	LOG Reduction	**-1.16**	**-1.19**	**-1.69**	**-6.60**

Net percent reduction and CADR values by particle size after 60 minutes in chamber:

Net Particulate Reduction and CADR by Size Range (60-Minute Endpoint)

Trial Id	Ultra-Fine (<0.543µm) Relative % Remaining	Fine (0.5 - 0.8µm) Relative % Remaining	Alveolar (0.8 - 5µm) Relative % Remaining	Coarse (5 - 20µm) Relative % Remaining
Impeccable Air	6.95%	6.51%	2.06%	0.000072%
Control	69.05%	72.34%	48.72%	1.022685%
NET Reduction	89.94%	91.00%	95.77%	99.9929%
Clean Air Delivery Rate (CFM)	22.52	23.97	30.22	108.91

V. Conclusions

This study evaluated the performance of the Impeccable Air Return Vent Filter in reducing airborne concentrations of both volatile organic compounds (VOCs) and particulate matter within a controlled environmental chamber simulating HVAC integration. Over the course of 60- minute trials, the filter demonstrated VOC removal, achieving net log reductions of 0.06 for formaldehyde and 0.10 for limonene. These represent improvements over natural decay observed in control conditions.

Particulate testing showed marked greater efficacy, with performance increasing alongside particle size. Net percent reductions after 60 minutes were 89.94% for ultrafine particles (<0.543 µm), 91.00% for fine particles (0.5–0.8 µm), 95.77% for alveolar particles (0.8–5 µm), and 99.99% for coarse particles (5–20 µm).

These results translated to CADR values of 22.52 CFM, 23.97 CFM, 30.22 CFM, and 108.91 CFM, respectively. Natural log decay plots and detailed trial data further support these findings.

Overall, the Impeccable Air Return Vent Filter demonstrated effective reduction of targeted VOCs and strong performance across a broad range of particle sizes. These results suggest meaningful potential for improving indoor air quality when used within HVAC systems as directed.