Effective Filtration of PM 2.5 in Air Cleaners and Masks

Analysis of the effectiveness of various air cleaners and masks in the filtration of PM 2.5

Cindy (Se Yeon) Choi, Seungho Choi, Alexander Kenny Guo, Ethan Jan

PBL Science 2013 – 2014

Ms. Debra Monroe

Friday, 6th June 2014

INTRODUCTION

Types of Pollutants

- VOC (Volatile Organic Compounds)
    - Toxic gases emitted by organic chemicals at room temperature
    - Originate from everyday products
    - Cause various health problems
    - More easily evaporated than SVOCs
    - i.e.) Formaldehyde, benzene, toluene, xylene
- SVOC (Semi-Volatile Organic Compounds)
    - Substances with higher boiling point than water emitted by organic chemicals
    - May vaporize when exposed to temperatures above room temperature
    - Cause various health problems
    - More harmful than VOCs
    - i.e.) PAE, PAH
- Simpler Pollutant Molecules:
    - i.e.) PM 2.5, PM 10, CO_2, NH_3, etc.

Process of Finding Concentration of VOCs & SVOCs

- Equation: Concentration (C) = $\frac{Mass\ (m)}{Volume\ (V)}$
- Sampler: Collect samples of VOC or SVOC
    a. In case of VOC: Absorption tubes used to sample
        i. GC/MS
    b. In case of SVOC: Absorption pipes used to sample
        i. Spectrophotometer: Conducts chemical analysis to calculate concentration

Particulate Matter

Particulate matter is a major air pollutant that is composed of mixtures of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles3.

Particulate matter is categorized based on the size of the particles (coarse and fine). Coarse particles are classified as particles from 2.5 μm to 10 μm (PM10). These particles are found near roadways and dusty factories. These particles are capable of being inhaled through normal bodies and may even reach the lungs4. Fine particles, on the other hand, are smaller than 2.5 μm (PM2.5), and are mainly found after combustion, including forest fires, gas emitted from power plants, factories, and automobiles. PM2.5 also can reduce visibility, producing haze and smog.

Particulate matter can have serious consequences on the health of individuals. Exposure to such particles can affect both one's lungs and heart. Numerous scientific studies have linked pollution exposure to a variety of problems, including:
• Premature death in people with heart or lung disease,
• Heart attacks,
• Irregular heartbeat,
• Aggravated asthma,
• Decreased lung function
• Lung irritation, coughing,
and difficult breathing5.

Along with aggravated negative health effects, particulate matter pollution also can have major environmental consequences.

PM2.5 can cause reduced visibility, as shown in the recent heavy pollution in Beijing in January 2013, where the pollution level reached 755 on the Air Quality Index (AQI), even above the original upper limit of 5006. It can also cause environmental damage – particles may enter bodies of water, including rivers, streams, and lakes, making them acidic. It can change the nutrient balance in coastal waters and large river basins, as well as depleting the nutrients in soil. This can deeply affect the biodiversity of the ecosystem in the area. Lastly, PM2.5 pollutants can stain or damage stone or other materials, including important objects such as statues and monuments.

Particulate matter is detrimental to both one's health and the environment. Most often, concentration levels of PM2.5 and PM10 are one of the most dominant pollutants in major cities, due to the constant combustion occurring inside factories and automobiles.

Air Cleaners

- 3 Main Types
    - Filtration:
        - Similar to masks: Capture & filter the pollutant particles in the air
        - Easiest and most efficient method
    - Absorption
        - Involve solvents forming solutions with pollutants
        - Solvents absorb pollutant particles in the air
    - Decomposition
        - Involve UV lights
        - Chemical components of pollutant particles decomposed under the light
        - Side effects: May form other pollutant compounds
- Mainly have fan, filter, and electric controller

"Good" Air Cleaner Qualities

- Effectively removes pollutants
- Easy regeneration and cleaning process
- No by-products created
- Low price & operation cost
- Quick purification process
- Remove multiple pollutants at once
- Suitable for a large area

National Standards for Air Cleaners

Clean Air Delivery Rate (measured in m^3/h)

This is a measurement for how powerful the air cleaner is. Literally speaking, it is the amount of air the cleaner can filter (in cubic meters) per hour. Based on standards, this is measured by first measuring the natural decay rate of the test chamber (without air cleaner on), to account for any leakages or surface absorption. Then, the total decay rate is recorded by measuring PM2.5 values for 20 minutes at 2 minute intervals with the air cleaner on. Then, we graph the data with the formula:

$$f(x) = \ln(x)$$

where x is the PM2.5 recording, and f(x) is the value after conversion. A linear line of best fit is then plotted on the log graphs of both the natural decay rate and the total decay rate. The respective slopes are recorded as KN and KE after taking the absolutevalue. Upon subtraction, a number is obtained, which is then multiplied by the volume of the test chamber, in cubic meters. This is the clean air delivery rate.

Efficiency

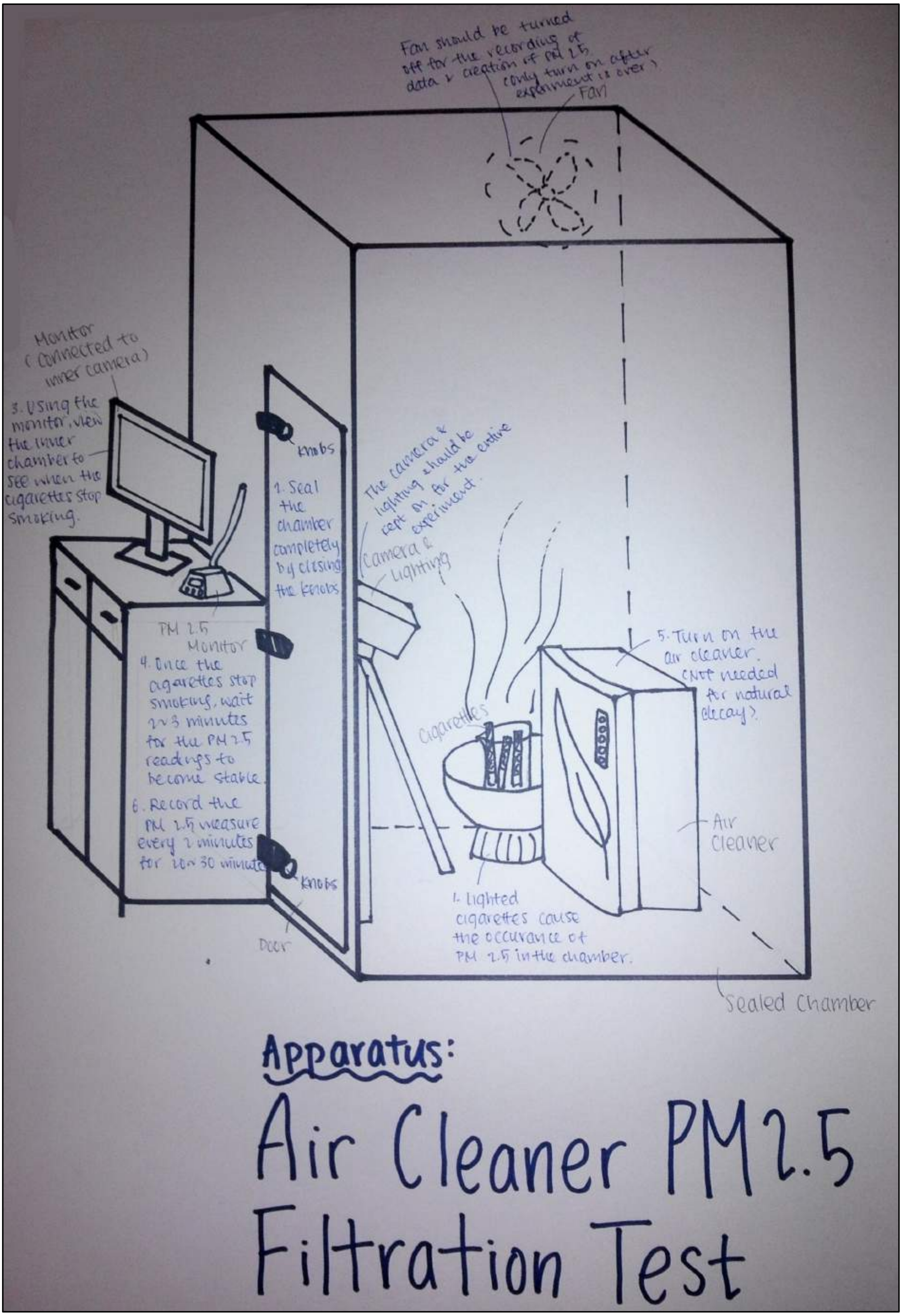
Efficiency takes into account the power output of each filter. Therefore, at a higher power output, the less efficient it is. The formula is as follows:

$$E = \frac{C}{P}$$

where E is the efficiency, C is the clean air delivery rate, and P is the power outputof the air cleaner.

AIR CLEANERS EXPERIMENT

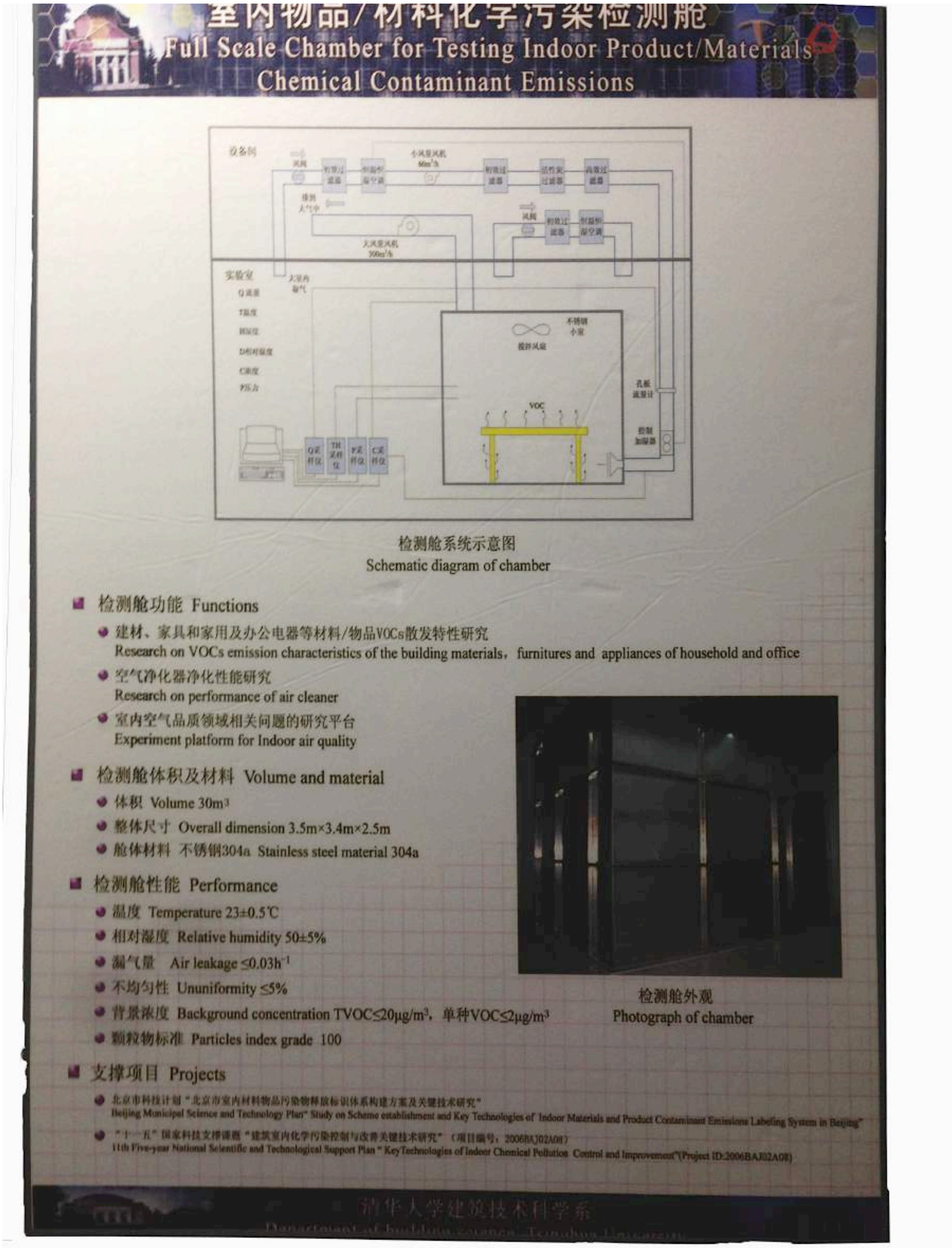
Apparatus Diagram



Procedure

We were able to test in "Full Scale Chamber for Testing Indoor Product/Materials" (Tsinghua Building Energy and Research Center), which was sealed with stainless metal. The volume of this chamber was 30m^3, and was equipped with power outlets on the inside, a fan inside for diffusion, controlled temperature and humidity, and outlet/inlet holes for PM2.5 measurement. It also had a camera for monitoring on the outside. TESTED PURIFIERS: BLUEAIR 403 and ENVION IONIC PRO TURBO.

Here are some specifications of the chamber:



1. Connect a PM 2.5 monitor to a tube linked to the inner air of the sealed chamber.
2. Light and place 3 cigarettes in a sealed chamber. Seal the chamber completely and turn off the fan.
3. Wait until the cigarettes stop smoking (as viewed from the computer monitor that records the situation inside the chamber) and the PM 2.5 measure becomes stable (as viewed from the PM 2.5 monitor).
4. Once the PM 2.5 measure is stable, start recording the natural decay rate of PM 2.5 by monitoring the PM 2.5 measure every 2 minutes for 20 minutes.
5. After 20 minutes are over, calculate the log value of each of the 10 PM 2.5 measures recorded.
6. Cleanse the air inside the chamber by turning on the fan. Wait until the PM 2.5 measure within the chamber becomes lower and fairly stable before unsealing the chamber.
7. Measure the power used by the chosen air cleaner.
8. Repeat steps 1 to 3 with 3 new cigarettes.
9. Turn on a chosen air cleaner. Wait for 2 – 3 minutes for the air cleaner to fully activate.
10. Begin recording the total decay rate of PM 2.5 under the influence of the chosen air cleaner by monitoring the PM 2.5 measures every 2 minutes for 20 minutes.
11. After 20 minutes are over, calculate the percentage decrease from the first measured value to the last measured value.
12. Calculate the log value of each of the 15 PM 2.5 measures recorded.
13. Calculate the clean air delivery rate of the chosen air cleaner.
14. Using the clean air delivery rate and the power previously measured, calculate the efficiency of the air cleaner (see introduction).
15. Repeat steps 7 – 14 for each air cleaner being tested.

Data Collection

Figure 1.1: Natural Decay of PM 2.5 Data Table

Time (min)	Natural Decay	Log. Of Nat.
0	360	5.89
2	358	5.88
4	351	5.86
6	353	5.87
8	355	5.87
10	351	5.86
12	352	5.86
14	361	5.89
16	358	5.88
18	350	5.86
20	352	5.86

Figure 1.2: PM 2.5 Natural Decay Rate Graph

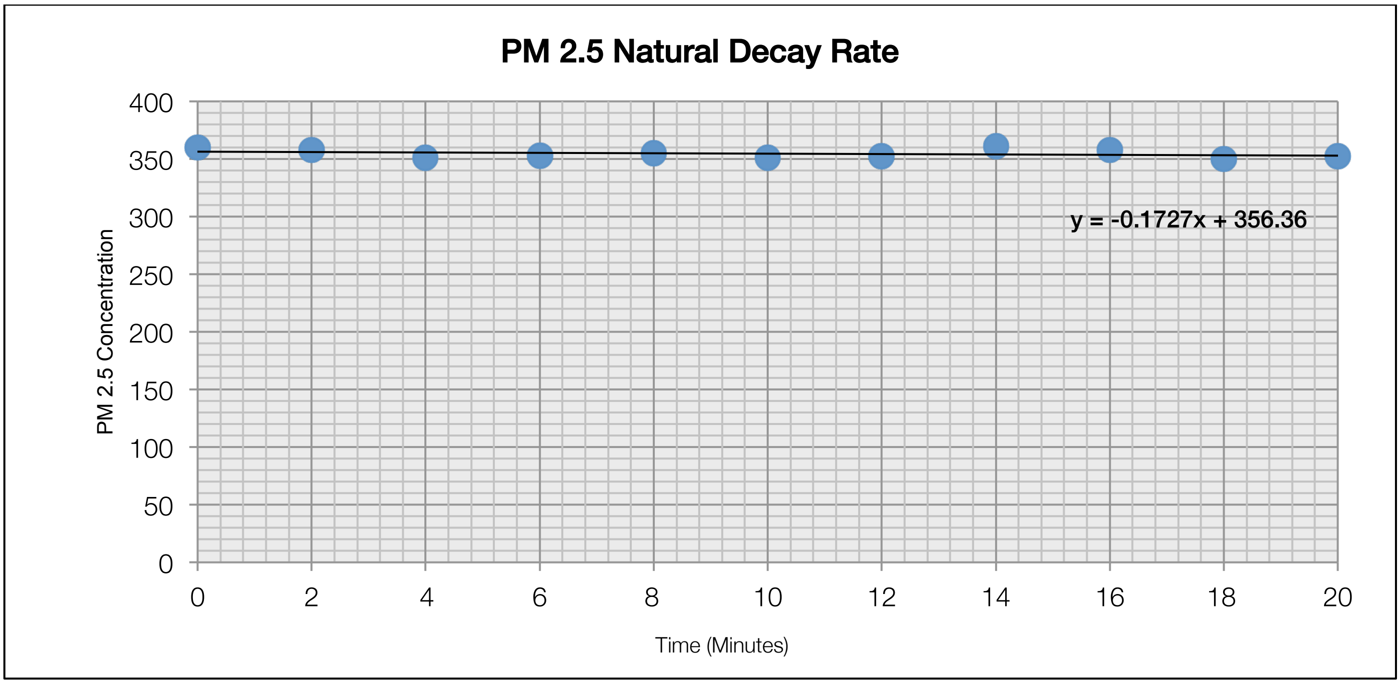


Figure 1.3: PM 2.5 Natural Decay Log Graph

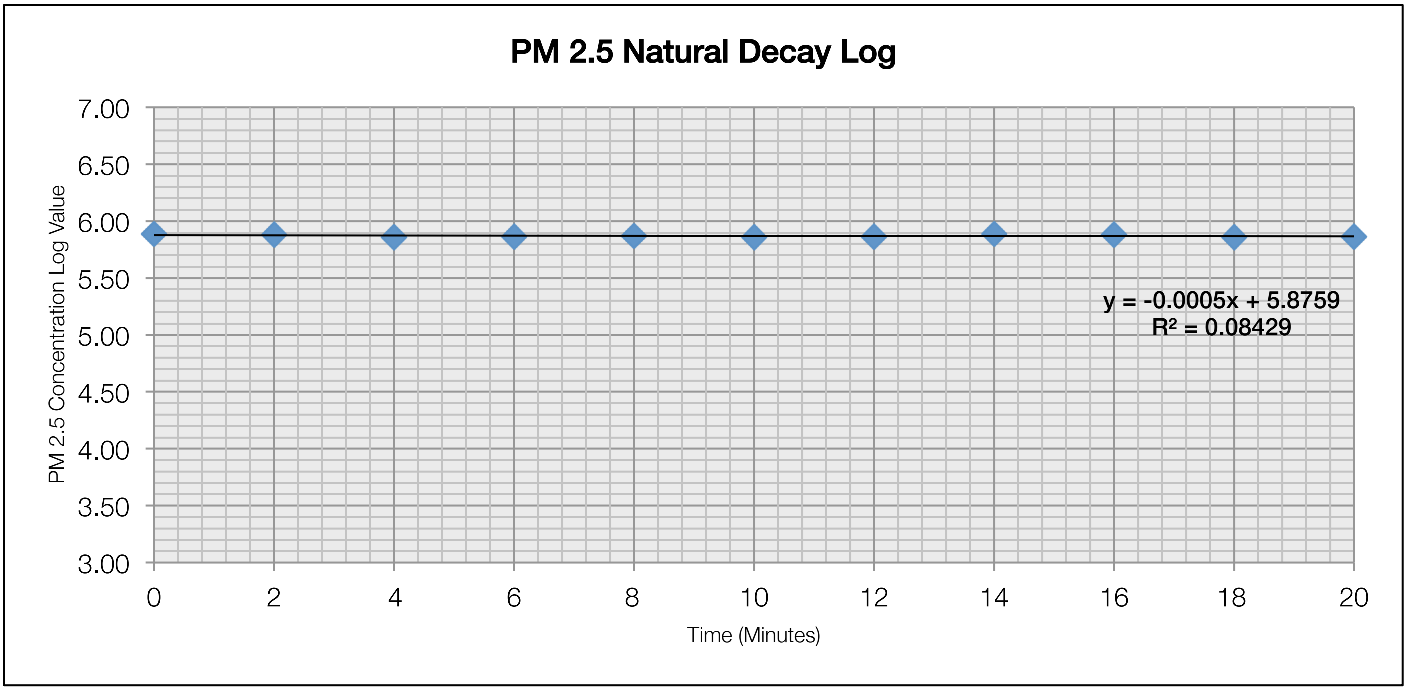


Figure 2.1: Blueair Maximum Airflow Data Table

Time (min)	Natural Decay	Log. Of Nat.	Time hr	Total Decay	Log of Tot.
0	360	5.89	0.00	355	5.87
2	358	5.88	0.03	292	5.68
4	351	5.86	0.07	258	5.55
6	353	5.87	0.10	226	5.42
8	355	5.87	0.13	176	5.17
10	351	5.86	0.17	141	4.95
12	352	5.86	0.20	113	4.73
14	361	5.89	0.23	87	4.47
16	358	5.88	0.27	68	4.22
18	350	5.86	0.30	53	3.97
20	352	5.86	0.33	43	3.76
			0.37	33	
			0.40	27	First-last (30)
			0.43	18	342.00
			0.47	16	% Decrease
			0.50	13	96.34%

KN	KE	Sub
0.0005	6.4727	6.4722
Clean Air Deliv. Rate		194.166
Power	Efficiency	Unit: m^3/h
35.5	5.47	

Figure 2.2: Blueair Maximum Airflow Total Decay Rate Graph

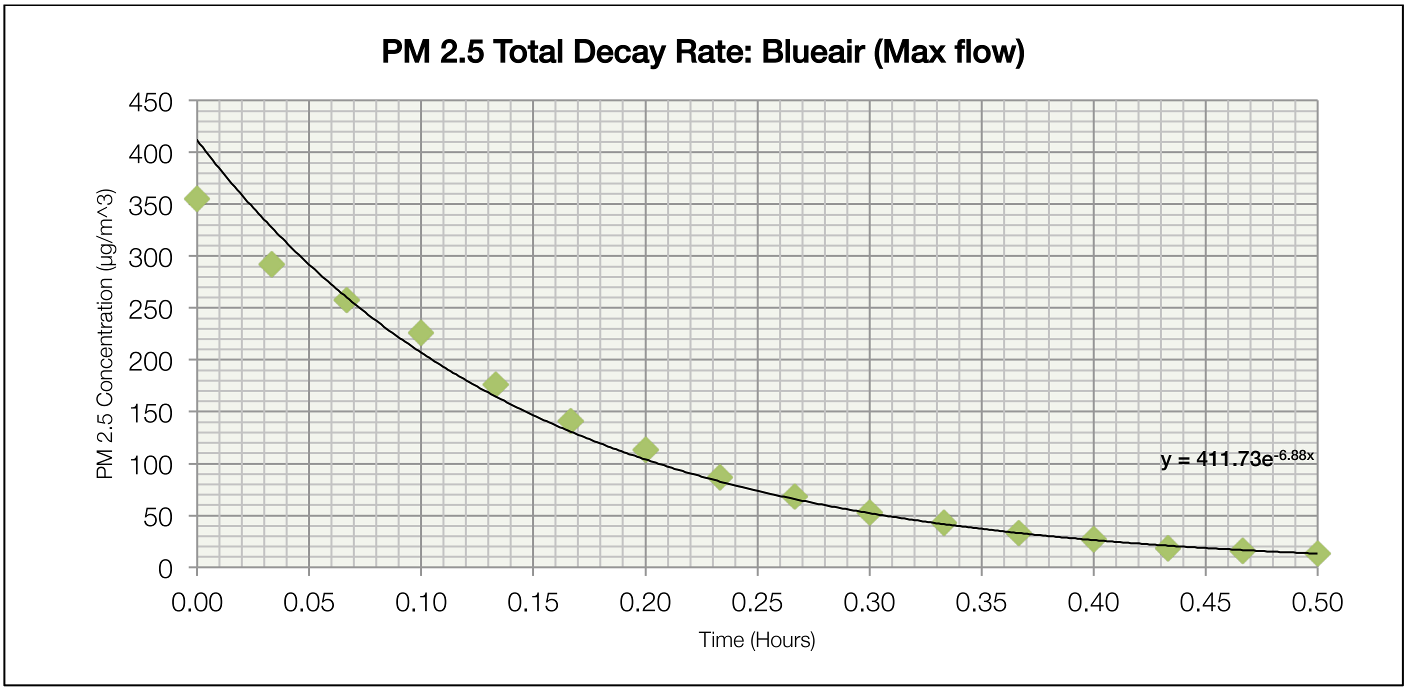


Figure 2.3: Blueair Maximum Airflow Total Decay Log Graph

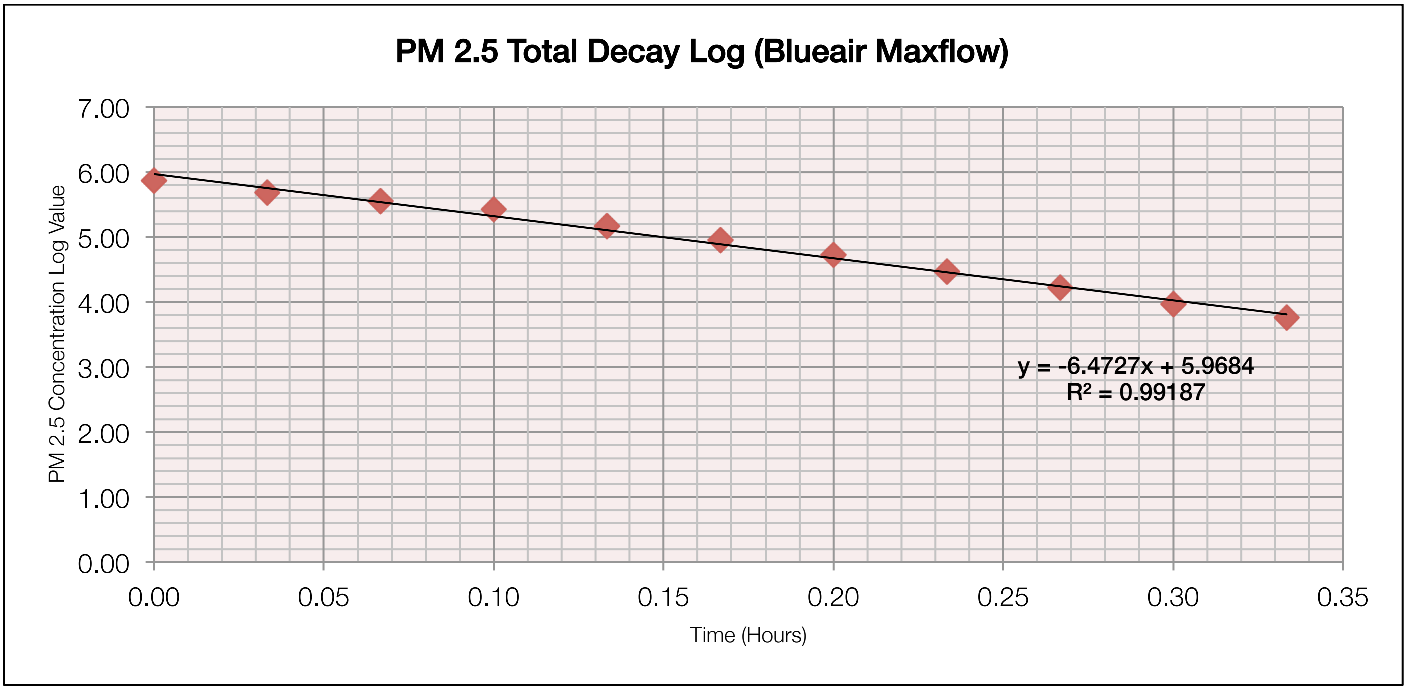


Figure 3.1: Blueair Hepasilent Data Table

Time (min)	Natural Decay	Log. Of Nat.	Time hr	Total Decay	Log
0	360	5.89	0.00	287	5.66
2	358	5.88	0.03	285	5.65
4	351	5.86	0.07	264	5.58
6	353	5.87	0.10	235	5.46
8	355	5.87	0.13	220	5.39
10	351	5.86	0.17	203	5.31
12	352	5.86	0.20	187	5.23
14	361	5.89	0.23	176	5.17
16	358	5.88	0.27	165	5.11
18	350	5.86	0.30	160	5.08
20	352	5.86	0.33	143	4.96
			0.37	132	
			0.40	126	First-last (30)
			0.43	116	186
			0.47	105	%Decrease
			0.50	101	64.81%

KN	KE	Sub
0.0005	2.1663	2.1658
Clean Air Deliv. Rate (*)		64.974
Power	Efficiency	m^3/h
7.03	9.24	

Figure 3.2: Blueair Hepasilent Total Decay Rate Graph

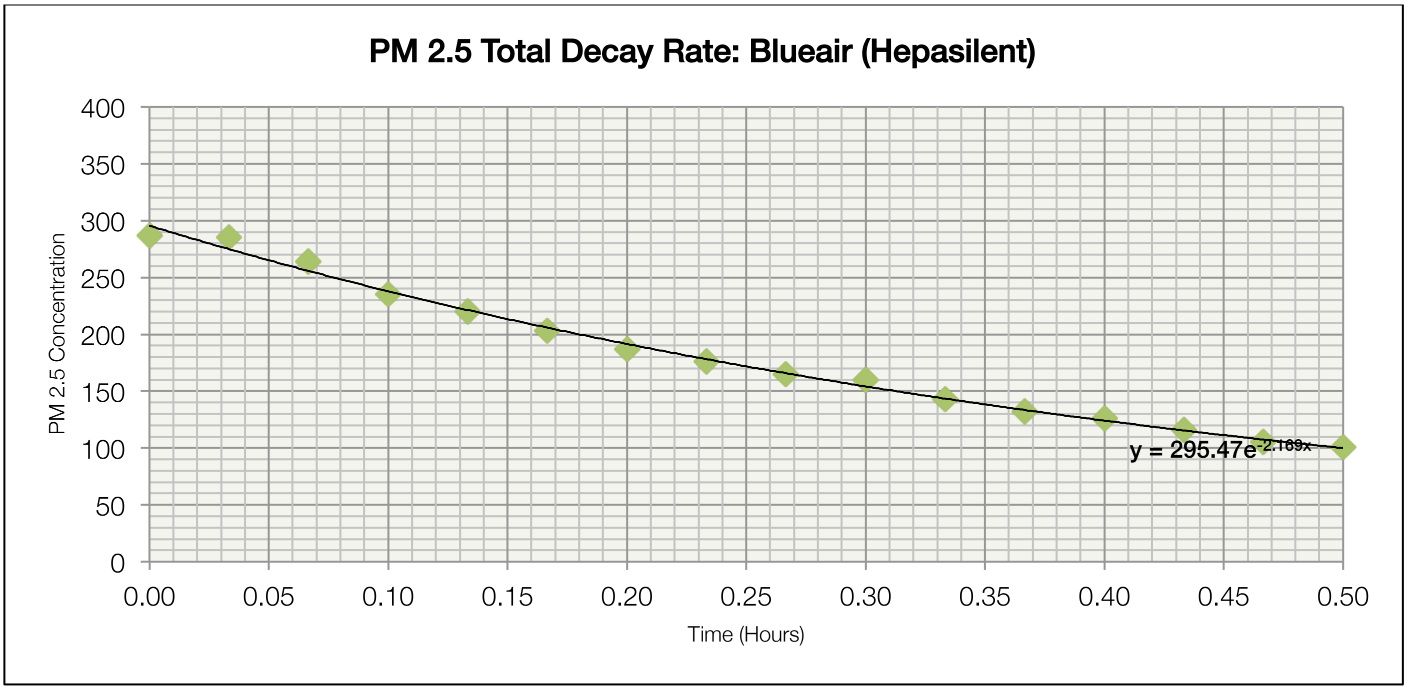


Figure 3.3: Blueair Hepasilent Total Decay Log Graph

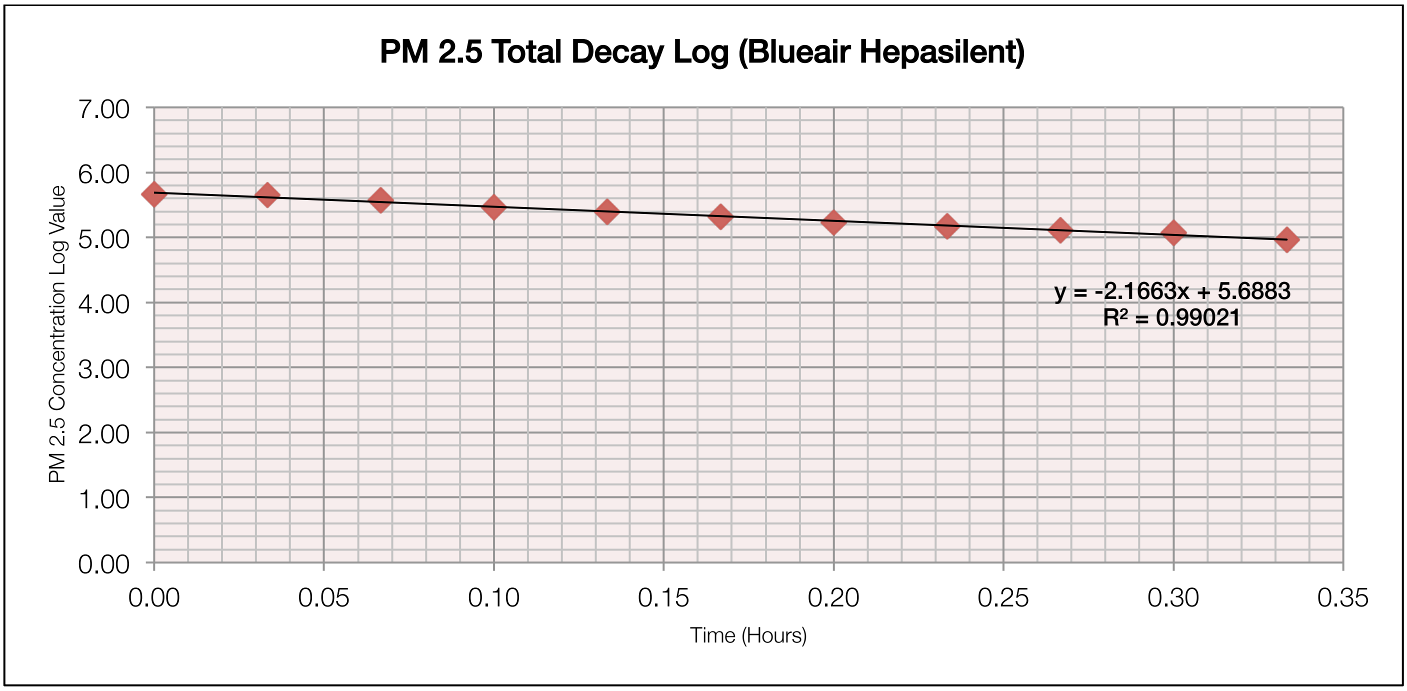


Figure 4.1: Ionic High Airflow 1 Data Table

Time (min)	Natural Decay	Log. Of Nat.	Time hr	Total Decay	Log
0	360	5.89	0.00	295	5.69
2	358	5.88	0.03	245	5.50
4	351	5.86	0.07	225	5.42
6	353	5.87	0.10	203	5.31
8	355	5.87	0.13	195	5.27
10	351	5.86	0.17	201	5.30
12	352	5.86	0.20	182	5.20
14	361	5.89	0.23	190	5.25
16	358	5.88	0.27	182	5.20
18	350	5.86	0.30	162	5.09
20	352	5.86	0.33	181	5.20
			0.37	150	
			0.40	158	First-last (30)
			0.43	141	155
			0.47	140	%Dec
			0.50	140	52.54%

KN	KE	Sub
0.0005	1.3458	1.3453
Clean Air Deliv. Rate (*)		40.359
Power	Efficiency	m^3/h
6.1	6.62	

Figure 4.2: Ionic High Airflow 1 Total Decay Rate Graph

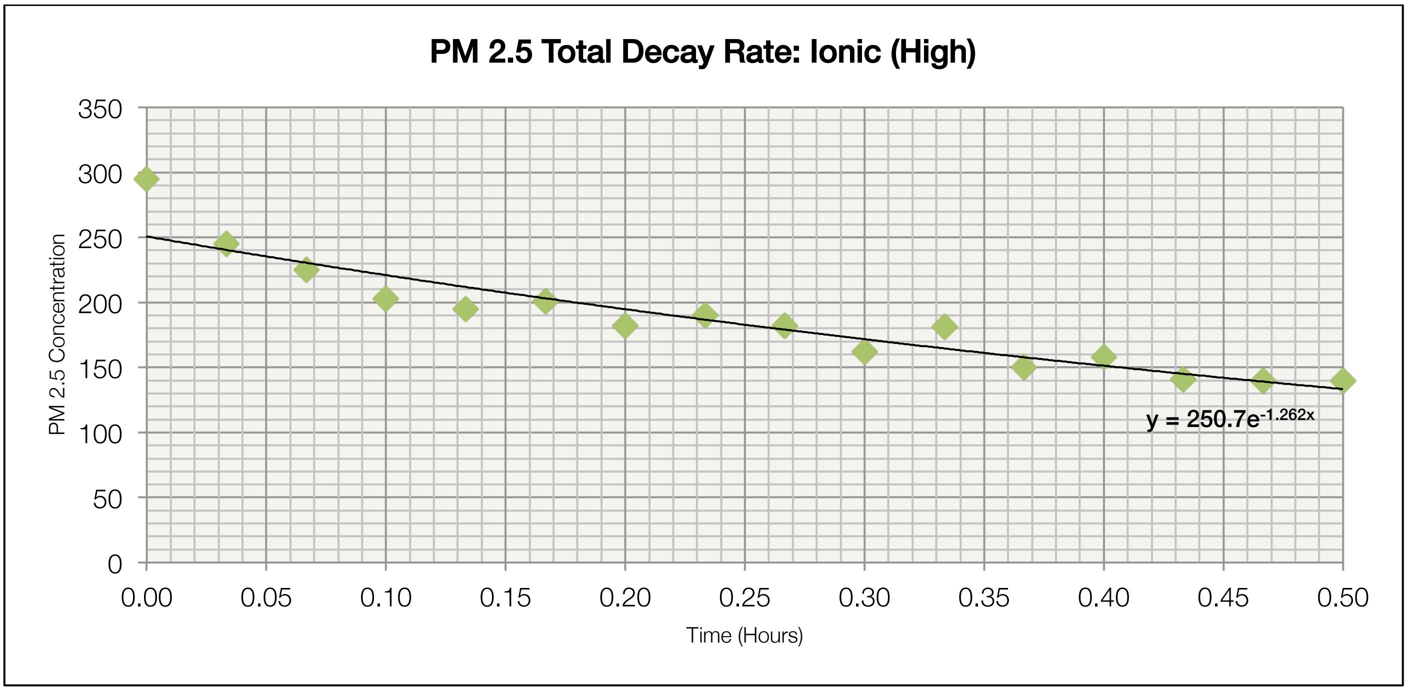


Figure 4.3: Ionic High Airflow 1 Total Decay Log Graph

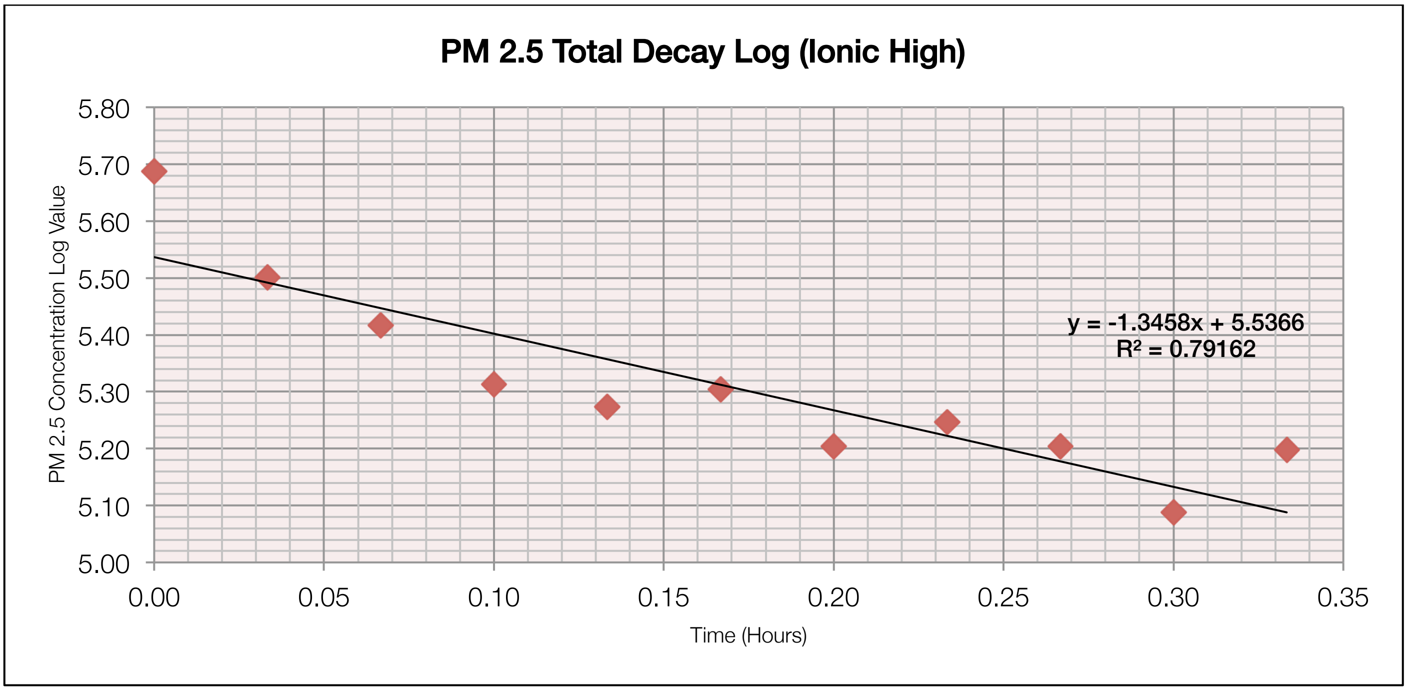


Figure 5.1: Ionic High Airflow 2 Data Table

Time (min)	Natural Decay	Log. Of Nat.	Time hr	Total Decay	Log
0	360	5.89	0.00	72	4.28
2	358	5.88	0.03	63	4.14
4	351	5.86	0.07	50	3.91
6	353	5.87	0.10	44	3.78
8	355	5.87	0.13	37	3.61
10	351	5.86	0.17	40	3.69
12	352	5.86	0.20	38	3.64
14	361	5.89	0.23	35	3.56
16	358	5.88	0.27	29	3.37
18	350	5.86	0.30	32	3.47
20	352	5.86	0.33	29	3.37
			0.37	34	
			0.40	32	First-last (30)
			0.43	31	42
			0.47	26	%Dec
			0.50	30	58.33%

KN	KE	Sub
0	2.5423	2.5423
Clean Air Deliv. Rate (*)		76.269
Power	Efficiency	m^3/h
6.1	12.50	

Figure 5.2: Ionic High Airflow 2 Total Decay Rate Graph

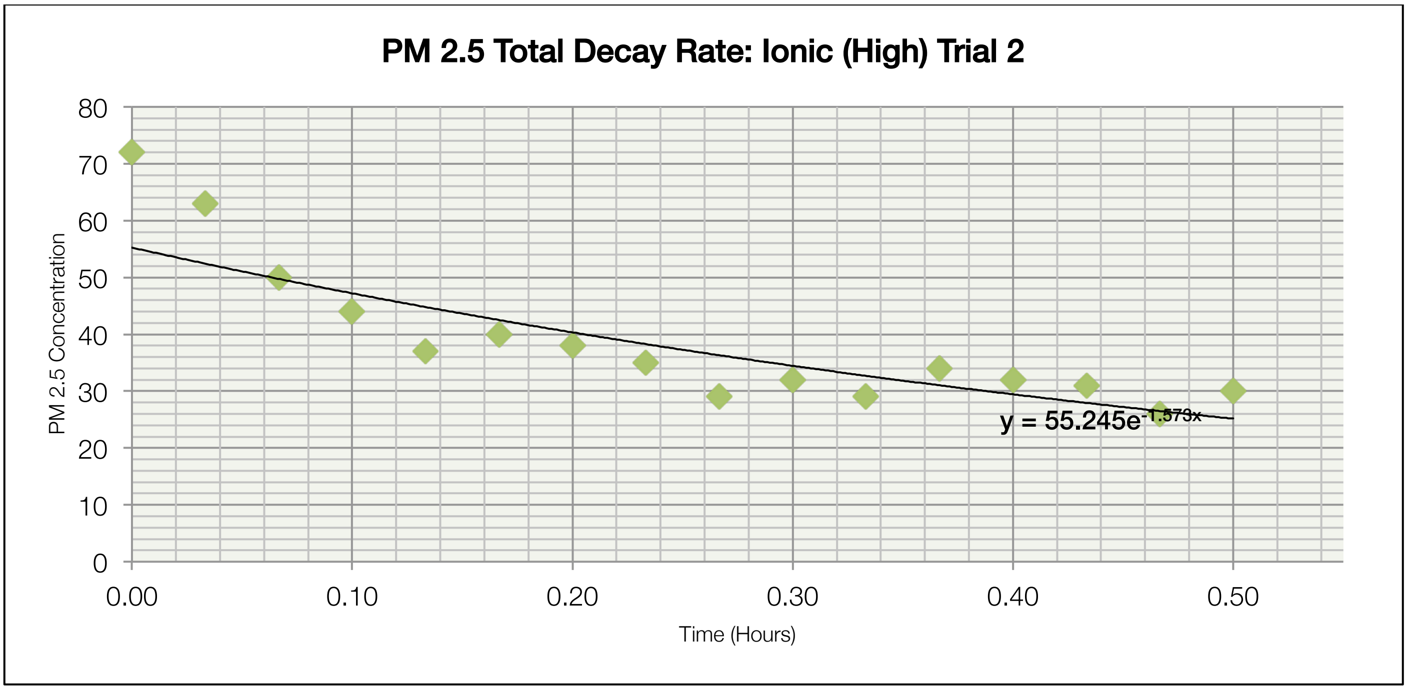


Figure 5.3: Ionic High Airflow 2 Total Decay Log Graph

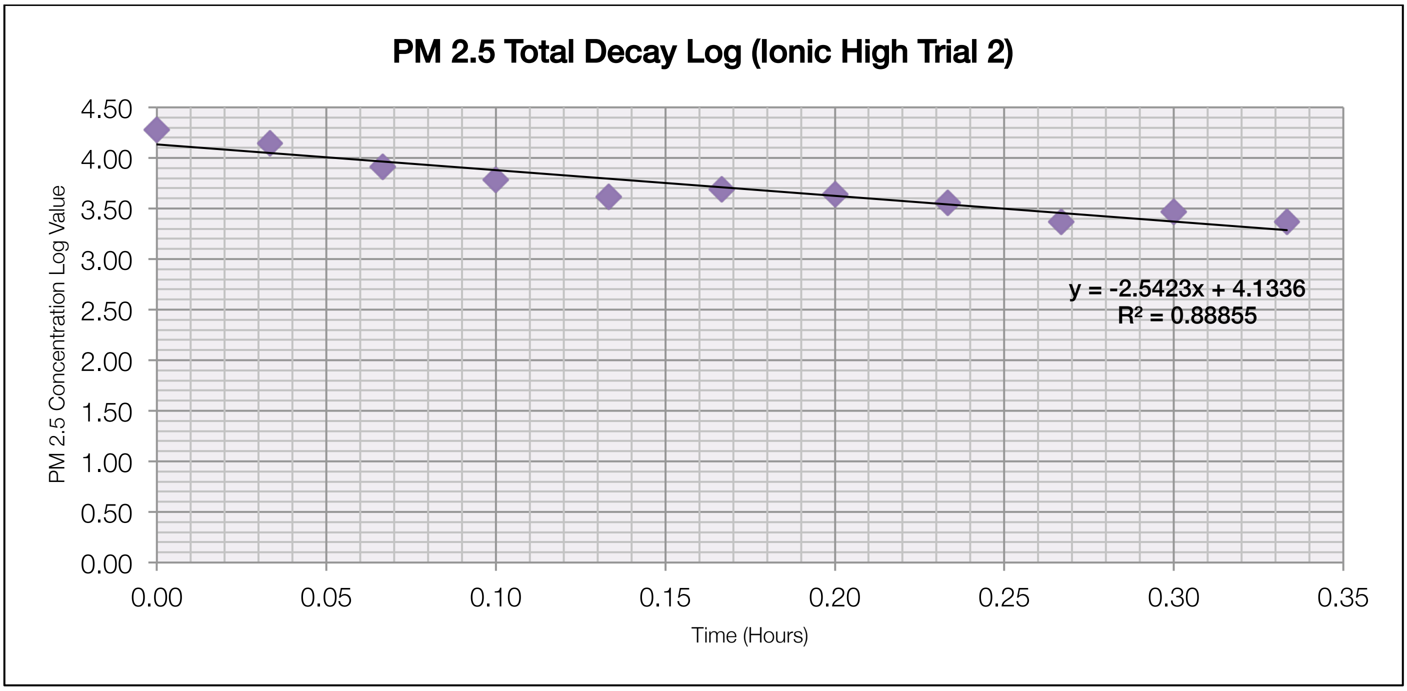


Figure 6: Comparative PM 2.5 Total Decay Rate

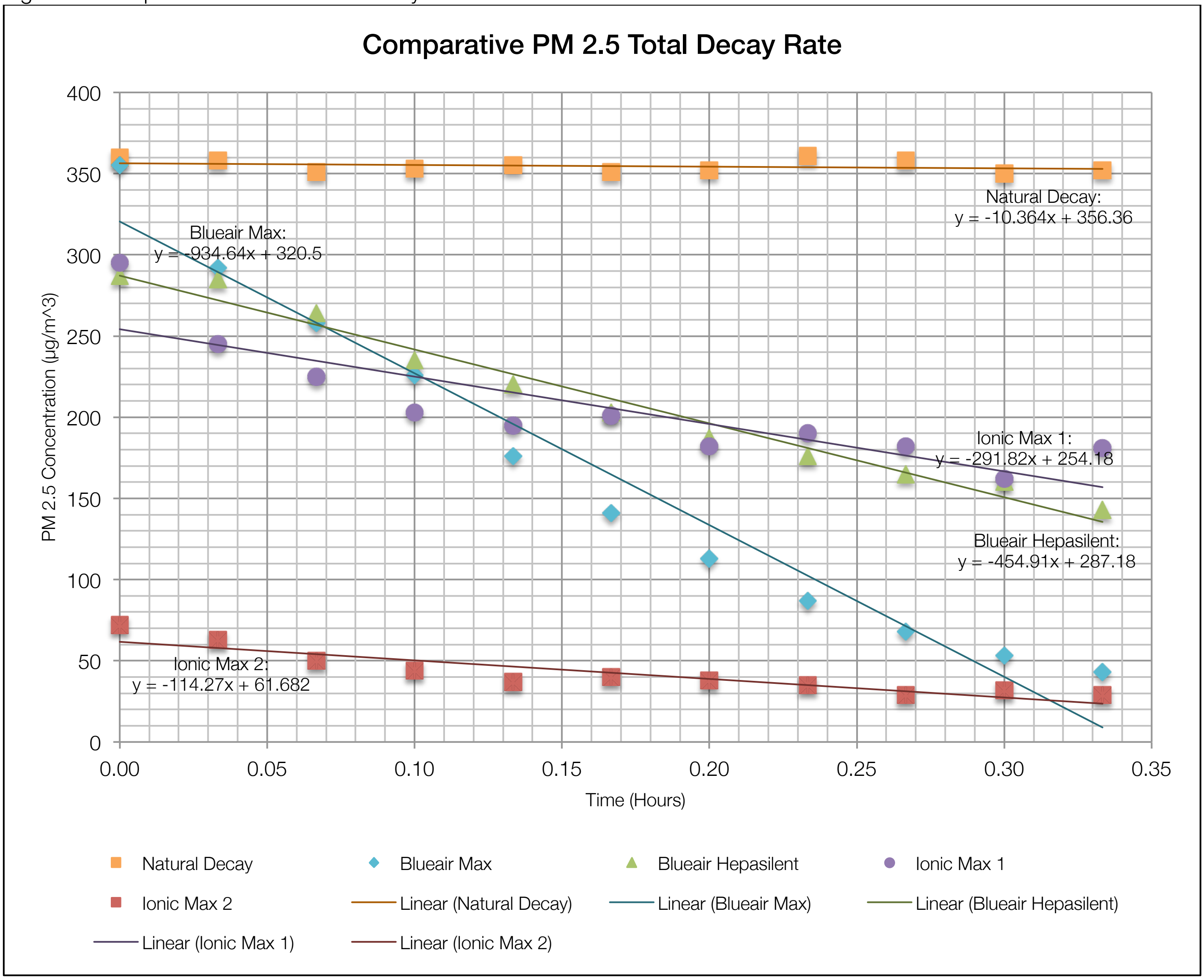


Figure 7: Comparative PM 2.5 Total Decay Log Values

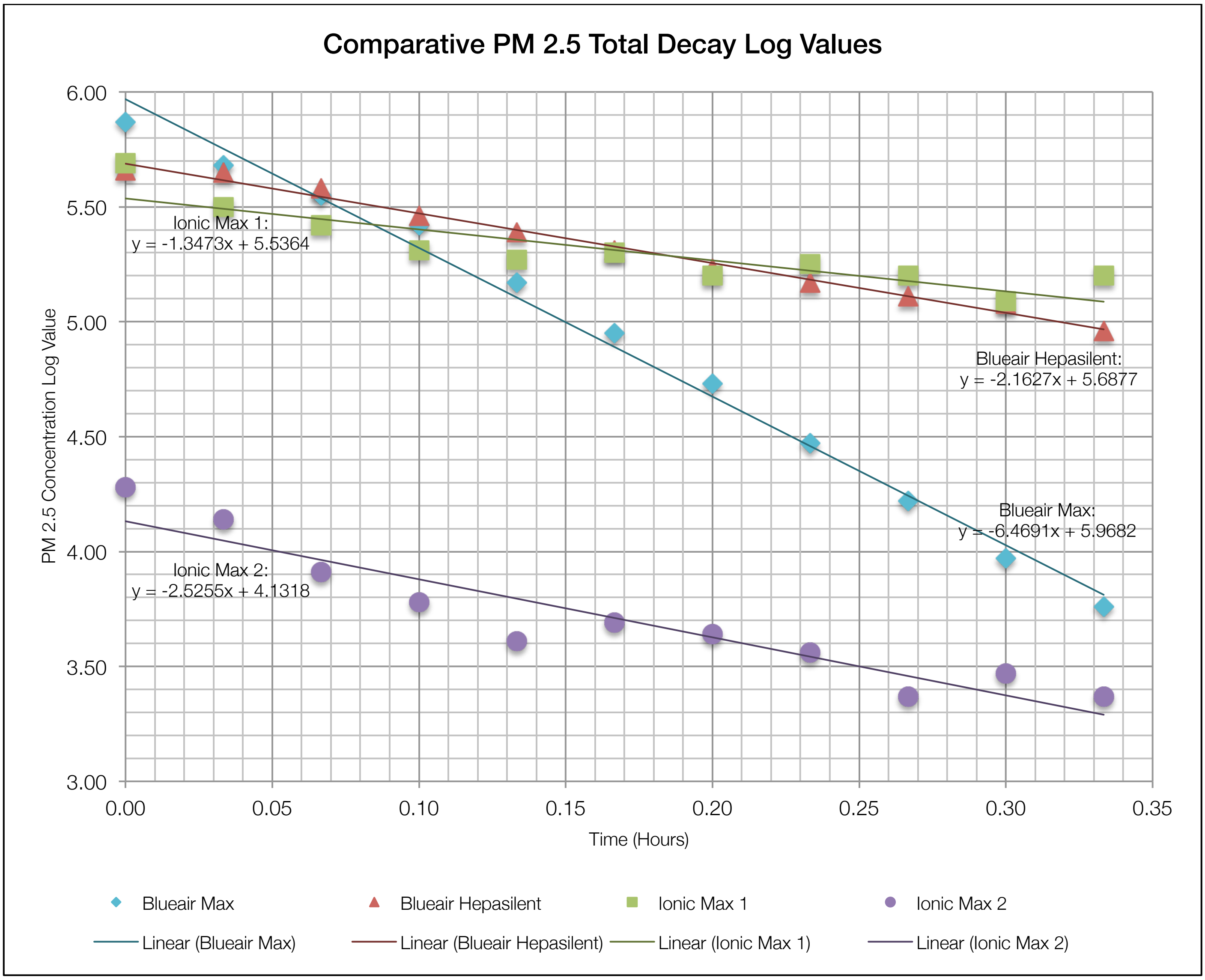


Figure 8: Comparative Clean Air Delivery Rate of Air Cleaners

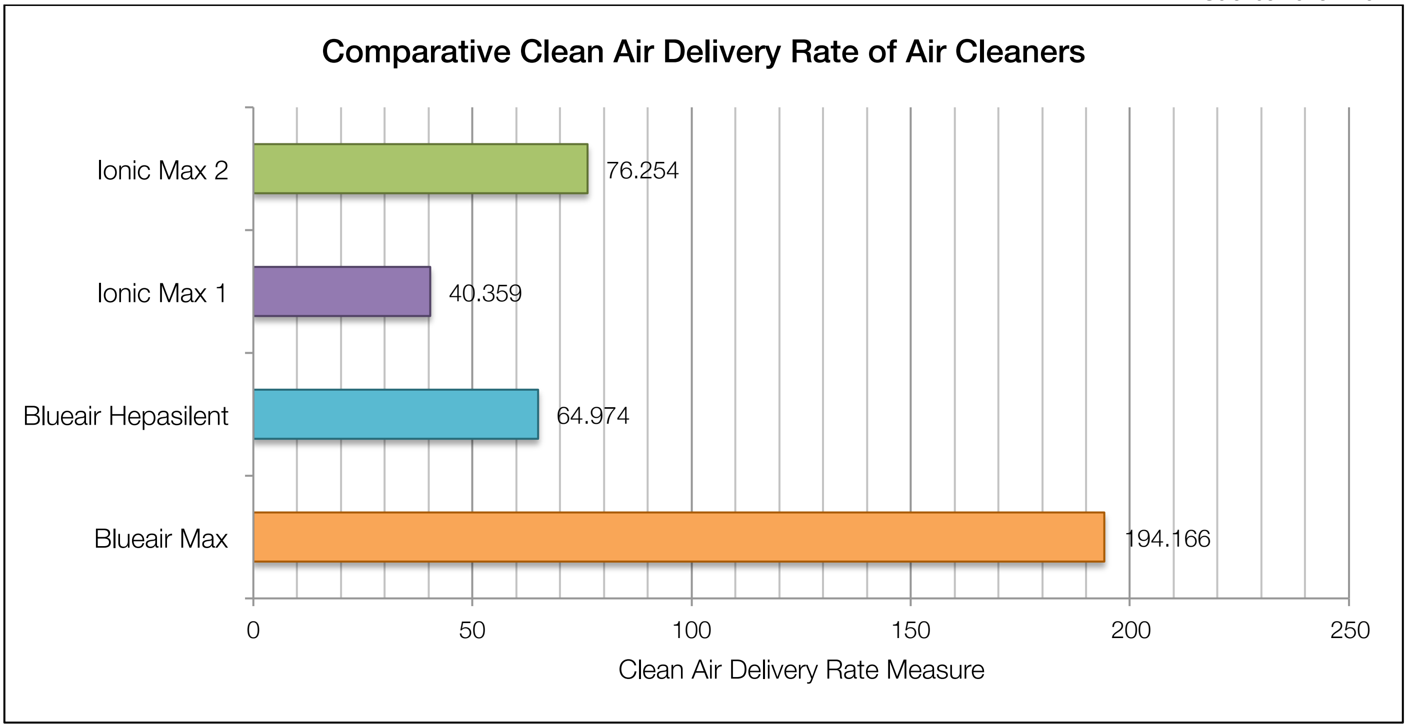
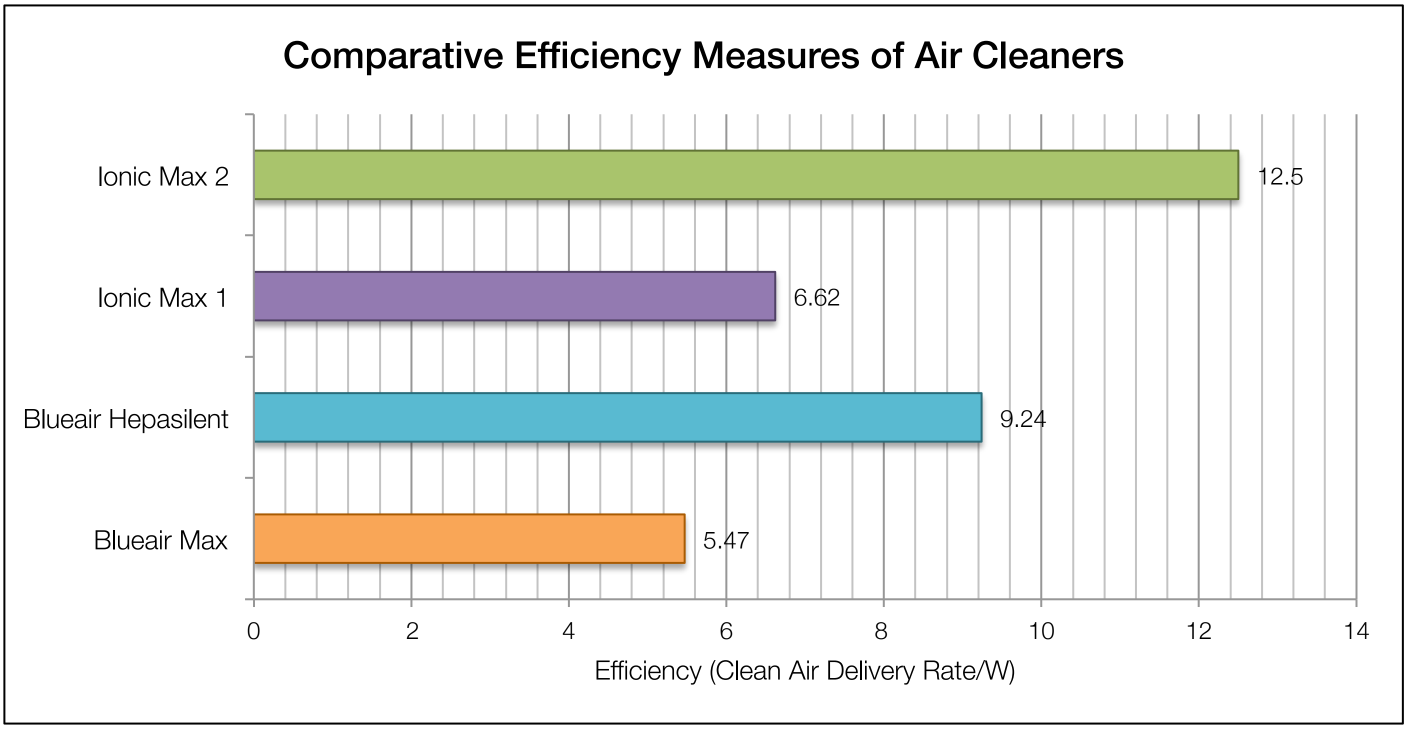


Figure 9: Comparative Efficiency Measures of Air Cleaners



Through these graphs and tables, it is possible to get a sense of which air cleaners are the most efficient or have the most power to quickly filter PM2.5 in a room. The first to graphs show a comparison between the two air cleaners in terms of clean air delivery rate, and the last two compare the air cleaners in terms of efficiency (see introduction).

It is apparent that the best air filter when it comes to the pure power of air cleaning is the BLUEAIR filter at its max setting. It has a clean air delivery rate of about 194 m^3/h, and can filter out over 96% of the PM2.5 inside a 30m^3 chamber in a short timespan of 30 minutes, in which we conducted our tests. The PM2.5 dropped from a massive 355μg/m^3 to an impressively low concentration of 13μg/m^3. In comparison, the BLUEAIR running the HEPASILENT mode (lowest) had a CADR of 65 m^3/h, with a decrease in PM2.5 of 65% in 30 minutes (287 to 101). The Ionic Pro air cleaners, which use a different removal method of PM2.5, we substantially worse in terms of CADR. Even on the highest setting, the Ionic Pro air cleaner was only able to deliver a CADR of 30m^3/h, decreasing only 52% of the PM2.5 in 30 minutes (295 to 140). We assumed this was because the cleaner was not meant to clean such high concentrations of PM2.5, and redid the test on the same setting with a lower starting PM2.5 concentration, which we controlled at 72. This time, the CADR was calculated to be 76, dropping 58% from 72 to 30 in 30 minutes. Looking at these measurements, the result of the Ionic Pro air filters are substandard when compared to the BLUEAIR filter.

However, when it comes to efficiency, the Ionic Pro air filter is not that bad. Because of its extremely low power consumption of a mere 6.01W, the Ionic Pro air filters recieved outstanding values of efficiency. The National standards for efficiency in China rates an efficiency of >2.5 as an “A” standard (highest). The Ionic Pro air purifier recieved an efficiency rating of 6.62 and 12.5 in our two tests. On the other hand, the power because of the higher power consumption of the BLUEAIR air purifiers, rated as 7.03W even on the HEPASILENT mode, and a staggering 35.5W on the MAX airflow mode. This, especially for the MAX airflow mode, brings the efficiency of the filter down to only 5.47, even with its higher CADR of almost 200. However, this is still impressive when compared to the Chinese national standards as stated earlier.

Now let’s examine the pricing for these two filters. The ENVION Ionic Pro Turbo Air purifier costs USD $180, while the BLUEAIR 403 air filter costs USD $550 (according to amazon.com). Such a large difference in price corresponds to a similarly large difference in the ability of each filter to purify the air.

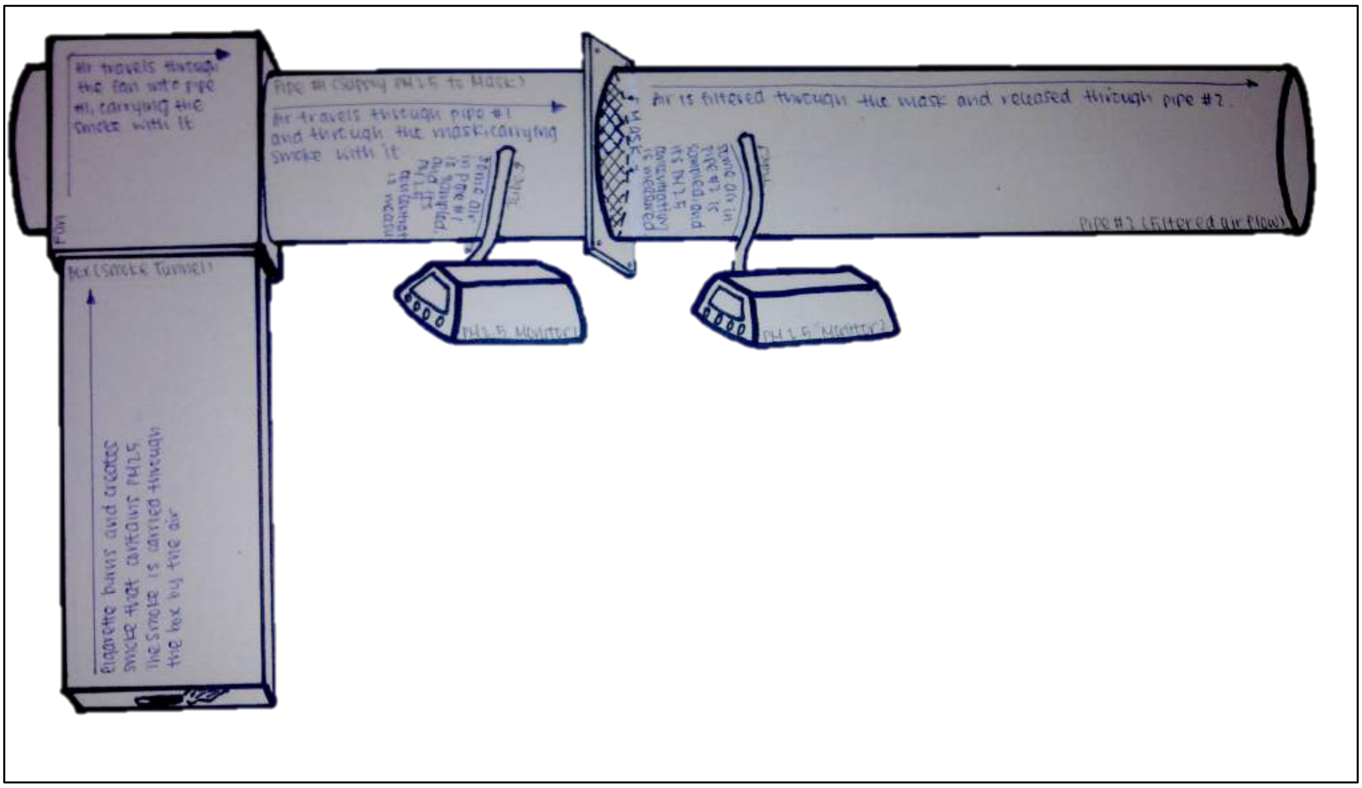
Because we conducted our tests in a sealed chamber and followed national and international standards for measurement, our results can be considered quite reliable. For example, we measured not only total decay but also natural decay to account for surface absorption and air leakage inside the chamber. However, something we could have done better is to have a controlled PM2.5 “creator,” instead of using cigarettes, which produced different start values.

All in all, the results show that the BLUEAIR filter is worth the money it costs – it clearly excels when it comes to CADR and purifying your home, if you don’t mind a slightly greater electricity bill.

Cindy Choi, Seungho Choi, Alex Guo, Ethan Jan
PBL Science 2013 – 2014

MASK EXPERIMENT

Apparatus Diagram



Procedure

1. Fix the shorter pipe of the two to the fan with sealing tape. Make sure that there is no air leaking between the pipe and the fan.
2. Fix a mask onto the longer pipe of the two given pipes. Make sure that the mask is completely sealed with the sealing tape.
3. Seal the two pipes together first with bolts and nuts then with sealing tape. Make sure that the air does not leak between the two pipes.
4. Fix a PM 2.5 monitor on each pipe through the holes on the pipes.
5. Turn on the fan. Start the timer and record each of the PM 2.5 measures given by the two monitors every minute for 10 minutes.
6. Stop the timer.
7. Light a cigarette and hold it near the fan. Start the timer again and record each of the PM 2.5 measures given by the two monitors every minute for 5 minutes.
8. Stop the timer.
9. Unseal the two pipes. Take off the mask from the longer pipe and replace it with another mask.
10. Repeat steps 1 – 9 for each mask being tested.

Data Collection

Figure 10.1: Doctor Mask Natural PM 2.5 Filtration Data Table

	Time (Min)	Before Mask PM 2.5 Concentration (µg/m^3)	After Mask Concentration (µg/m^3)	Percentage Filtered (%)
Doctor Mask Natural PM 2.5	0	150	91	39.33%
	1	146	90	38.36%
	2	148	91	38.51%
	3	143	89	37.76%
	4	140	88	37.14%
	5	132	84	36.36%
	6	139	86	38.13%
	7	139	86	38.13%
	8	135	83	38.52%
	9	134	82	38.81%
	10	140	86	38.57%
	Average	140.55	86.91	38.16%
	Average Percentage Filtered		38.16%	

Figure 10.2: Doctor Mask PM 2.5 Filtration Graph

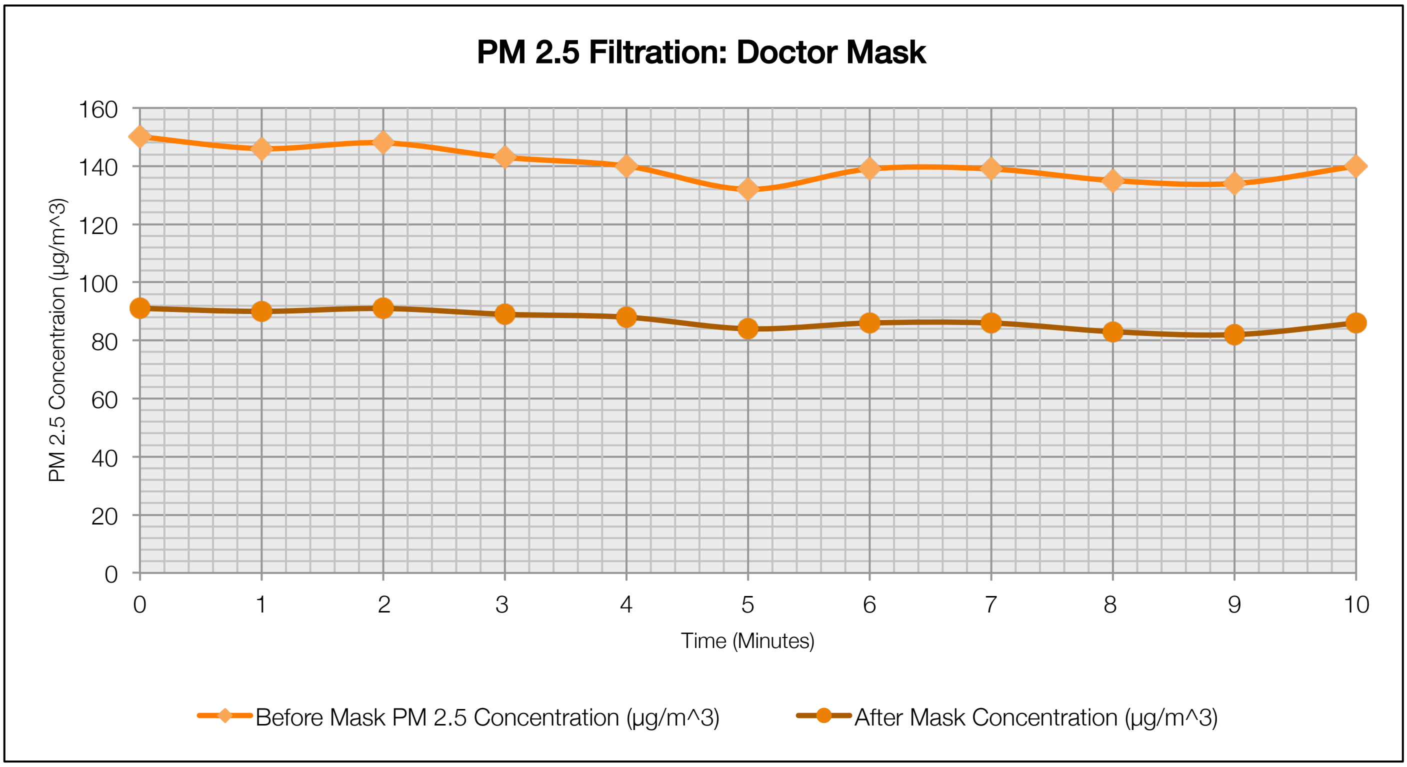


Figure 10.3: Doctor Mask Cigarette PM 2.5 Filtration Data Table

	Time (Min)	Before Mask PM 2.5 Concentration (µg/m^3)	After Mask Concentration (µg/m^3)	Percentage Filtered (%)
Doctor Mask Cigarette PM 2.5	0	5770	4510	21.84%
	1	9030	5560	38.43%
	2	1030	721	30.00%
	3	30600	16500	46.08%
	4	734	495	32.56%
	5	3550	2180	38.59%
	Average	4610.36	2724.18	40.91%
	Average Percentage Filtered		40.91%	

Figure 11.1: 3M 8210V Natural PM 2.5 Filtration Data Table

	Time (Min)	Before Mask PM 2.5 Concentration (μg/m^3)	After Mask Concentration (μg/m^3)	Percentage Filtered (%)
3M 8210V Natural PM 2.5	0	146	1	99.32%
	1	138	1	99.28%
	2	139	1	99.28%
	3	139	1	99.28%
	4	132	1	99.24%
	5	135	1	99.26%
	6	129	1	99.22%
	7	137	1	99.27%
	8	143	1	99.30%
	9	138	1	99.28%
	10	140	1	99.29%
	Average	137.82	1.00	99.27%
	Average Percentage Filtered		99.27%	

Figure 11.2: 3M 8210V Natural PM 2.5 Filtration Graph

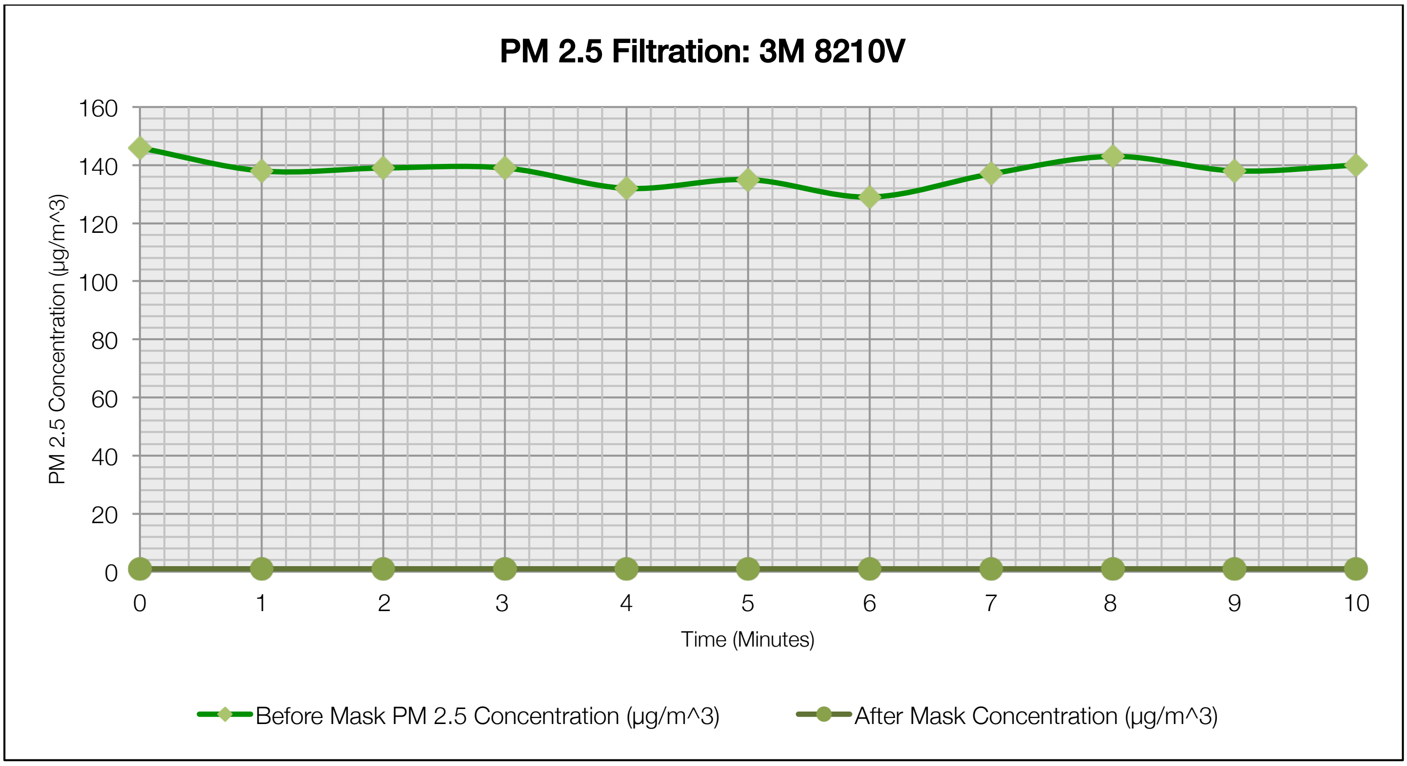


Figure 11.3: 3M 8210V Cigarette PM 2.5 Filtration Data Table

	Time (Min)	Before Mask PM 2.5 Concentration (μg/m^3)	After Mask Concentration (μg/m^3)	Percentage Filtered (%)
3M 8210V Cigarette PM 2.5	0	3230	105	96.75%
	1	407	11	97.30%
	2	729	16	97.81%
	3	257	3	98.83%
	4	1360	37	97.28%
	5	818	45	94.50%
	Average	618.27	19.73	96.81%
	Average Percentage Filtered		96.81%	

Figure 12.1: 3M 8200 Natural PM 2.5 Filtration Data Table

	Time (Min)	Before Mask PM 2.5 Concentration (μg/m^3)	After Mask Concentration (μg/m^3)	Percentage Filtered (%)
3M 8200 Natural PM 2.5	0	107	1	99.07%
	1	112	1	99.11%
	2	107	1	99.07%
	3	109	1	99.08%
	4	114	1	99.12%
	5	102	1	99.02%
	6	99	1	98.99%
	7	97	1	98.97%
	8	101	1	99.01%
	9	100	1	99.00%
	10	101	1	99.01%
	Average	104.45	1.00	99.04%
	Average Percentage Filtered		99.04%	

Figure 12.2: 3M 8200 Natural PM 2.5 Filtration Graph

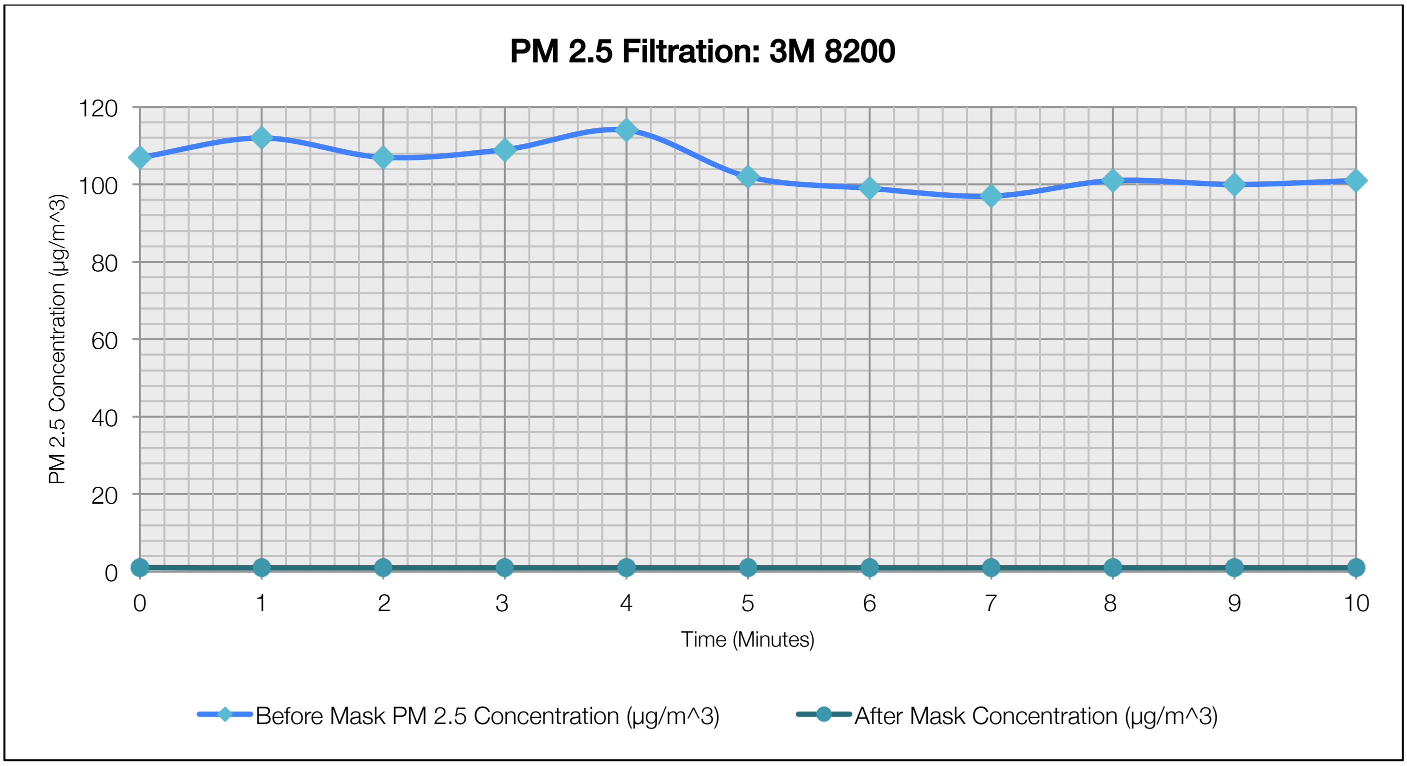


Figure 12.3: 3M 8200 Cigarette PM 2.5 Filtration Data Table

	Time (Min)	Before Mask PM 2.5 Concentration (μg/m^3)	After Mask Concentration (μg/m^3)	Percentage Filtered (%)
3M 8200 Cigarette PM 2.5	0	3010	123	95.91%
	1	2300	92	96.00%
	2	504	24	95.24%
	3	1210	40	96.69%
	4	759	29	96.18%
	5	240	6	97.50%
	Average	757.13	28.91	96.18%
	Average Percentage Filtered		96.18%	

Figure 13.1: Oh Sunny Natural PM 2.5 Filtration Data Table

	Time (Min)	Before Mask PM 2.5 Concentration (µg/m^3)	After Mask Concentration (µg/m^3)	Percentage Filtered (%)
Oh Sunny Natural PM 2.5	0	95	77	18.95%
	1	96	77	19.79%
	2	98	80	18.37%
	3	97	78	19.59%
	4	98	79	19.39%
	5	96	78	18.75%
	6	96	77	19.79%
	7	97	78	19.59%
	8	97	79	18.56%
	9	97	80	17.53%
	10	96	79	17.71%
	Average	96.64	78.36	18.91%
	Average Percentage Filtered		18.91%	

Figure 13.2: Oh Sunny Natural PM 2.5 Filtration Graph

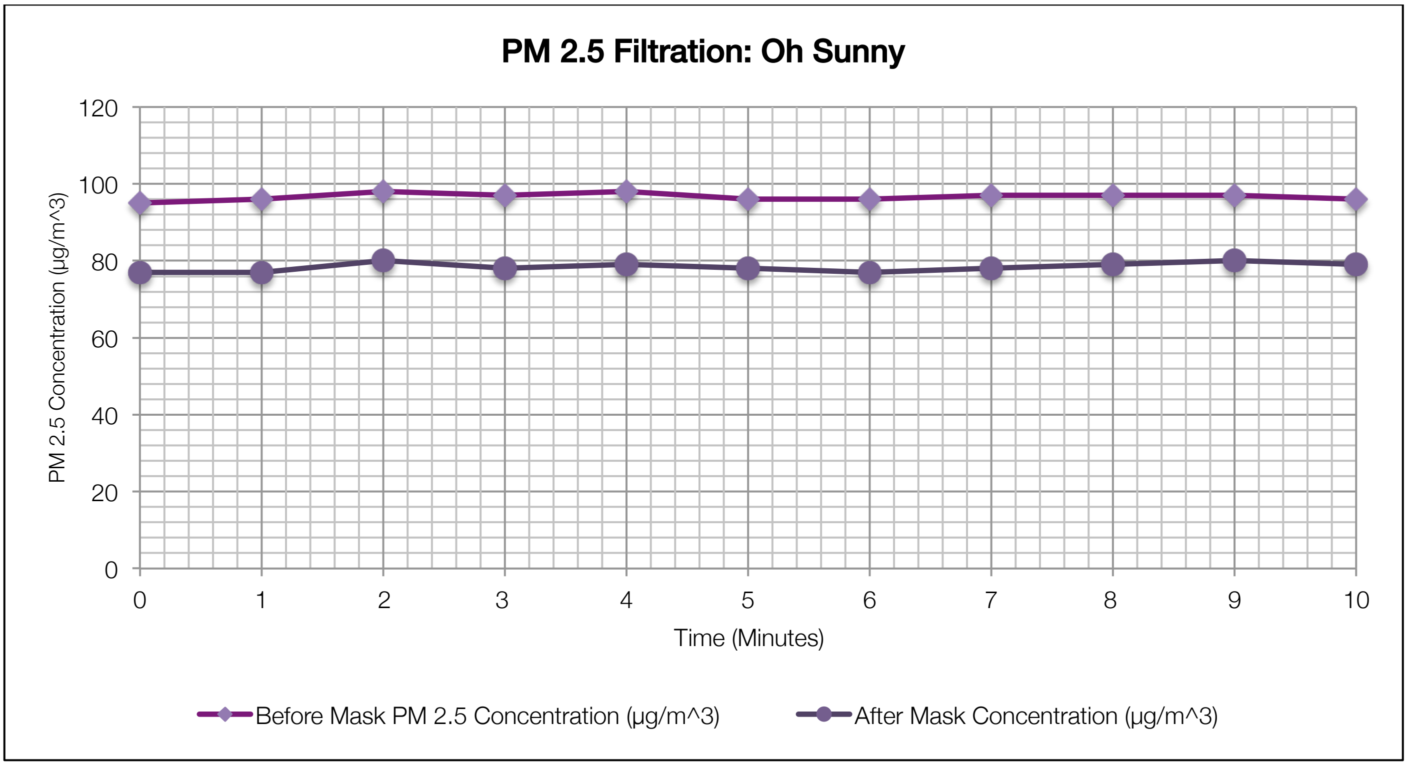


Figure 13.3: Oh Sunny Cigarette PM 2.5 Filtration Data Table

	Time (Min)	Before Mask PM 2.5 Concentration (µg/m^3)	After Mask Concentration (µg/m^3)	Percentage Filtered (%)
Oh Sunny Cigarette PM 2.5	0	1710	1390	18.71%
	1	717	611	14.78%
	2	2060	1680	18.45%
	3	928	809	12.82%
	4	2720	2160	20.59%
	5	1130	995	11.95%
	Average	842.27	695.00	17.49%
	Average Percentage Filtered		17.49%	

These graphs and tables show the individual efficiencies of all the masks we tested. Bought on Taobao.com, the masks had a varying price range, but we all within 50RMB.

We conducted two tests for each of these masks: one on the PM2.5 filtration in a natural setting, where we blew natural Beijing air into the mask to obtain PM2.5 measurements for both pre-filtration and post-filtration. The PM2.5 concentration on that day of testing (Thursday, June 5, 2014) was ~100μg/m^3, which was a suitably high concentration to test in. After performing the tests, we felt we needed to increase the input PM2.5 value, to see how the masks would perform at almost impractical PM2.5 concentrations. Therefore, we lit cigarettes, and put them near the inflow for the air blowing machine, resulting in extremely high PM2.5 concentrations for the pre-filtration measurements. The highest measurement we recorded was 30,600μg/m3.

There was a massive difference in terms of filtration efficiency when it came to the four masks. The doctor mask, a typical hospital mask, performed better than we thought it would, filtering out 38.16% of the PM2.5 in a natural setting (avg 140μg/m3 pre-filtration and 86.91μg/m3 post-filtration), and a similar 40.91% of the PM2.5 in the cigarette setting (avg 4610μg/m3 pre-filtration and 2724μg/m3 post-filtration).

The Oh Sunny UV protection mask performed the worst in all of our tests, filtering out only 18.91% of the PM2.5 in a natural setting (avg 96.64μg/m3 pre-filtration and 78.36μg/m3 post-filtration), and a similar 17.49% of the PM2.5 in a cigarette setting (avg 842.27μg/m3 pre-filtration and 695.00μg/m3 post-filtration). These results show that this mask is unsuitable for PM2.5 filtration.m.

Both the doctor mask and the Oh Sunny mask were completely dwarfed by both 3M N95 masks, which filtered out >95% of the PM2.5 in all the tests we performed on them. The masks filtered out an impresive 99.27% and 99.04%, respectively, of the PM2.5 in a natural setting (avg 137.82μg/m3 and 618.27 μg/m3 pre-filtration, respectively, and <1μg/m3 post-filtration for both masks), and a similar 96.81% and 96.18%, respectively, of the PM2.5 in a cigarette setting (avg 618.27μg/m3 and 757.13 pre-filtration, respectively, and 19.73 μg/m3 and 28.91μg/m3 post-filtration, respectively). These outstanding results prove that these NIOSH approved N95 masks performed incredibly well in all of our filtration tests at all concentration of PM2.5, making it the most suitable masks to protect against the harms of these airborne pollutants of all the masks we tested.

The masks experiment had some limitations: for example, we could not mimic an actual face shape when testing, so we assumed the masks are tightly sealed to your face, allowing no air to get in without being filtered by the masks. In reality, this is impossible and completely depends on the mask used, so will have some inaccuracies. Also, using the cigarettes was highly inconsistent, because the PM2.5 readings from them fluctuated so much it was impossible to graph. However, even with these inconsistencies, the ratio between pre-filtration and post-filtration remained constant.

In conclusion, the mask experiments have taught us that buying NIOSH N95 masks is strongly recommended. It filters air by a staggeringly impressive amount, and we assume has a tighter fit on your skin when compared to the hospital mask.

ACKNOWLEDGEMENTS FOR ALL EXPERIMENTS:

Tsinghua University Indoor Air Quality Test Lab, Department of Building Science School of Architecture, Building Energy Research Center, Beijing National Center of Electron Microscopy, Department of Environment; Bu Zhongming, Ph.D student, Zhou Wei, Ph.D. Student, Yuan Rui, Ph.D.

REFERENCES:

Method for Measuring Performance of Portable Household Electric Room Air Cleaners. Rep. AC ed. Vol. ANSI/AHAM. Washington DC: Association of Home Appliance Manufacturers, 2006. Print. 1-2006.

中华人民共和国国家质量监督检验检疫总局. 空气净化器. Rep. 18801st ed. Vol. GB/T. 泰皇岛: 中国国家标准化管理委员会, 2008. Print. 中华人民共和国国家标准.

Sultan, Z. M., G. Nilsson, R. J. Magee, and J. S. Bradley. Method for Testing Portable Air Cleaners. Rep. 54013th ed. Vol. NRCC. Canada: Institute for Research in Construction, 2011. Print.