ADVANCED IAQ SOLUTIONS, INC.
A DEFINITIVE APPROACH TO INDOOR AIR QUALITY

Greentech Pure Air 750 with ODOgard prefilter w/ MERV 10 filter

Objectives:
An infield evaluation of the Pure Air 750 w/ ODOGard prefilter wall mount unit combined with a MERV 10 pleated filter as to measurable results and overall impact to indoor air quality in a typical commercial setting.

Location:
1501 Lehigh St. testing suite
Project start: 10/11/21 to 10/15/21
Conducted by: Keith Roe, CIE/CMC, Advanced IAQ Solutions, Inc

Testing Environment:
Room 203 is a two-room finished commercial suite of about 1240 sq.ft. with painted drywall ceilings and walls, used carpeting and a suspended ceiling. There is an interior office area of about 168 sq.ft/ 1344 cu. ft. that the test was conducted in. The connecting door to the larger room was closed. The forced air HVAC system was not operating during the test. A 120 cfm box fan was attached to a MERV 10 filter and operated continuously inside the room after the initial inoculation period and after Day 1 testing was completed mid-day. This provided approximately 5 air turns per hour of filtered air. No HVAC system was operating so there was no fresh air ventilation and the condition in the room could be described as a *stale air* condition. The single supply and return register in the room was not sealed at the client's request.

Location of the wall unit:
The unit was installed on the inside 14' wall about 6.5 ft. from the floor.

Definitions of Technology:
The 750 unit contains Active Radiant Catalysis (ARC) a proprietary form of Photocatalytic Oxidation. The unit also contained an ODOGard treated pre filter.

Testing Preparation:
Prior to the testing, the room was vacuumed using a HEPA filtered vacuum, and all horizontal surfaces were wiped clean. VOC sources from two scented liquid cleaners, 2 ounces of Simple Green and Citrus Cleaner that both contain Limonene and 2 oz. of liquid formaldehyde were introduced into the room environment from (4) saturated sponges that remained exposed to the indoor environment during the 5-day period. Also (3) MEA agar Petri dishes newly inoculated with multiple ubiquitous molds and (3) TSA agar petri dishes newly inoculated with multiple ubiquitous bacteria were left exposed inside the room during the testing.

Testing Sequence

Day 1- 10/11/21 prior to the wall unit operating, the first set of samples were taken and IAQ monitoring was performed after the room inoculations had been introduced over the prior 24-hour period. At the completion of that testing the wall unit was turned on.

Day 2 to 5- 10/12/21 to 10/15/21- The wall unit was operated continuously as was the 150 cfm fan that circulated air through a MERV 10 filter.

Sampling/Monitoring Protocols Used:

1. **Spore Trap Mold Testing**:

   150 liter air samples were taken before the installation (day 1), during (Day 3), and at the end of the testing (day 5) in the room 203, in the adjacent hallway(indoor control) and outside(outside baseline) . These samples were analyzed by AEML Labs using Microscopy for total spore count identified by each mold genus. (see Addendum A, pg. 1,2 for further testing details). It is standard protocol to take both an indoor control and outdoor control when performing spore trap testing to serve as a comparison to untreated areas. nce.
2. **Particle Impactor Sampling:**
   These air samples were taken daily within the room 203, on days 1, 3 and 5 in the same locations in the center of the room. These samples were sealed, refrigerated and submitted to Focus Labs within 1 hour for incubation, culture and identification of total detectable *viable* mold spores that are capable of reproduction given the necessary moisture and growth host. The lab followed ISO 14698, protocol 023. (see Addendum A, pg. 3 for further sampling details)
3. **Surface Sampling: Swab sample method**
   These surface samples were taken simultaneously with the air samples on days 1,3 and 5. The dusty surface of the same supply register was sampled for 4 sq.in. using a sterile Stuart transport swab. These swabs were sealed and refrigerated and submitted to Focus Labs within I hour. They were incubated and analyzed for total CFU (colony forming units) for both mild and bacteria. The lab followed ISO 14698, protocol 023. (further detail in Addendum A, pg. 4)
4. **TO-15-Summa type VOC sampling**
   This testing method allows the identification of parts per trillion of certain volatile organic compounds and look at unknown compounds and make tentative identifications if newly formed compounds are present. This test was performed prior to the testing and on days 3 and 5 of the testing representing a 24 hour time period between each sampling. (further detail in Addendum A, pg. 5,6,7)
5. **TVOC (Total Volatile Organic Compounds) and Formaldehyde (HCHO) gas monitoring:**
   Using a newly calibrated TemTop model LKC-1000 a laser multi-functional detector with a high precision electrochemical sensor that can transform the concentration of pollutants in the air into visual data, readings were taken daily during the project. The TVOC reading that this unit provides is representative of multiple airborne compounds that were present simultaneously and are reported in mg/m3 allowing low levels to be detected and reported. A VOC PID meter was used to report the VOC levels present in ppm.

HCHO (formaldehyde), Formaldehyde is the most common aldehyde in the environment. The natural

background concentration is < 1 ug/m3 with a mean average of about 0.5 ug/me. Also a common indoor contaminant used in many products and disinfectants.
Levels were also monitored daily and the readings are part of the integrated results and are reported separately but part of the TVOC component reported by the TemTop Meter. These total results were reported in mg/m3. (milligram per cubic meter) providing very low detection levels.
Also each day a new passive sampler badge containing silica gel coated with 2,4 dinitrophenylhydazine was exposed for 24 hours to the indoor environment within 20' of the sampling table. Each sampler was sealed and sent to EMSL Analytical Labs for analysis using NIOSH method 2016 for quantitative analysis of formaldehyde content to quantitatively define the airborne concentration in the room. The detection limit for this passive method is 0.002 mg/m3. (see Appendix A, pg. 11)

6. **PM2.5, PM10.0**
   These are inhalable particle matter (PM) not a single pollutant, but a mixture of many chemical species. It is a complex mixture of solids and aerosols comprised of small droplets of liquid, dry solid fragments, and solid cores with liquid coatings. Those with a diameter of 10 microns or less (PM10) are inhalable into the lungs and can induce adverse Health effects. *Fine* particle matter is defined as particles that are 2.5 microns or less in diameter and comprises a portion of the PM10. These levels are regulated by an OSHO standard of exposure in the workplace. These were measured daily using a calibrated TemTop model LKC-1000 laser detector with a high precision electrochemical sensor.

7. **Respirable (dust) Particle Counts:**
   Airborne particle sizes are measured in microns. Usually particle size is designated as the average diameter in microns. Particles less than 10 microns in diameter can get deep into your lungs and some may even pass into your bloodstream. Smaller particles (1-3 microns) diffuse deeply into your lungs tissue, depositing in the alveoli by a number of mechanisms including diffusion, sedimentation and electrostatic effects.

   Using a recently calibrated Extech VPC300 Video Particle Counter, particle sizes 0.3, 0.5, 1.0,2.5, 5.0 and 10.0 microns were measured daily during the project.

8. **Activated Oxygen (O3)**
   Using an Aeroqual portable ozone monitor, the ozone levels were monitored daily and were able to be reported at levels from 1 to 100 ppb. A data log function was also engaged. The current TLV TWA is .1 ppm.

9. **Odor Intensity**
   Using a portable Kanomax OMX-ADM intensity monitor, the levels were monitored daily over the 5-day period. The meter will show a numeric value between 1 to 999.

10. **RH% and Temperature**
    These environmental factors were monitored to determine if there was a discernible impact in the overall performance of the equipment when significant fluctuations of these factors occur.

11. **Carbon Dioxide- Co2 levels**

Co2 is a colorless, odorless, incombustible gas that forms during respiration, combustion and organic composition. It occurs naturally in the earth's atmosphere. Elevated indoor levels are often a result of poor fresh air ventilation creating a stale air environment that is prone to promote airborne diseases and viruses. The most commonly referenced standard is the ASHRAE standard 62.10 2015 defining a desired indoor level as < 1000 ppm. However recent research has defined that at < than 800 ppm for best disease transmission prevention. Levels above 5000 ppm cause illness and detrimental health effects.
NOTE: Levels <800ppm are reported to minimize the transmission of airborne viruses and diseases.

Findings:

1. **Mold Spore Trap Test Results**

Reference AEML report #344642, dated 10/11/21 (initial sampling)
These air samples were taken prior to the operation of the wall unit and filtered fan.
Sample #33146971, the outside spore total was reported for that day at a typical seasonal level of 1,813 s/m3.(spores /cubic meter)
Sample #33146952 Room 203 at 18,987*s/m3. A very high spore count.*
Sample # 33146949 (inside control) hallway was reported at 200 s/m3, a typical indoor level.
Reference AEML report # 344647, dated 10/13/21
These air samples were taken the 3rd day of the project after 48 hours of continuous operation.
Sample # 33147392 the outside spore count was reported on that day at 5,740 s/m3.
Sample # 33147360, Room 203 was reported at 113 s/m3, *>. a 99.9% reduction from the initial level.*
Sample # 33147075, Hallway was reported at 100 s/m3, *a 50% decline from the initial level.*
Reference AEML report # 344640, dated 10/15/21 - 5th day of testing
Sample # 33147034, outside was reported at 2,380 s/m3.
Sample # 33147064, room 203 was reported at only 233s/m3, an increase from day 3, but a reduction of > 99.9% from the initial level.
Sample # 33147082, Hallway was reported at 167/m3, a 67% increase from previous level but a 17% reduction from the initial level.

Overview:

A MERV 10 rated filter would provide a > 95% arrestance level for the average size of mold spores reported. This would suggest that this unit's combined technology contributed a 4-5% additional reduction factor.

IAQ Standards: *There are no set standards for airborne mold exposure, but a combination of several factors compiled by multiple agencies are frequently referenced (see addendum A, pg. 8) The reported mold spore levels in room 203 by day 6 were below those stated Guidelines.*

2. **Particle Impactor Air Sampling**

Reference: FOCUS Labs

Air Sample Results

Test Reference number 213647, dated 11-Oct-2021
A total of 248 cfu (colony forming units) of viable mold was reported.
A total of 37 cfu of airborne viable bacteria was reported.
Test Reference number: 213682,dated 13-Oct-2021
A total of >250 cfu of viable mold was reported.
A total of 14 cfu of viable bacteria was reported.

No significant reduction of viable mold was reported, bacteria was reduced by approx. 63%.
Test Reference number: 213735, dated 15-Oct-2021
A total of 17 cfu of viable mold was reported, mold was decreased from the previous reading by .
A total of 26 cfu of viable bacteria was reported.
Day 5 totals represented a > 93.% reduction of viable mold and 30% reduction in viable bacteria over the 4 days with RH% that would not significantly diminish continued growth of viable molds in the space. The RH% inside for those two days was 60.8 to 65.0%

Surface (swab) Sampling Results
These samples were taken from horizontal surfaces in the room.
Test Reference number 213646, dated 11-Oct-2021
A total number > 250 cfu of viable surface molds were reported.
A total number > 250 cfu of viable surface bacteria were reported.
Test Reference number 213675, dated 13-Oct-2021
A total number of 8 cfu viable surface mold was reported, *a 97% reduction over 2 days..*
A total number of 7 cfu viable surface bacteria was reported, a 97.5% reduction over 2 days.
Test Reference number 213723, dated 15-Oct-2021
A total number of 11 cfu of mold was reported on this day, a 95.6% reduction over 4 days.
A total number of 8 cfu of bacteria was reported, a 97% reduction over 4 days.

NOTE: No pathogenic mold or bacteria were introduced for safety reasons. These viable mold and bacteria are comprised of ubiquitous species introduced into the space initially and kept exposed to the indoor ambient air during the 5-day period.

4. TO-15 results
Reference EMSL report # 492100611 dated 10/11/21, the TVOC level reported at that time with this collection method was comprised of 14 separate compounds totaling 1200 ug/m3. The primary compound identified was D-limonene at 550 ug/m3, Ethanol was reported at 210 ug/m3. Three unknown compounds were reported at a combined total of 376 ug/m3.
Reference EMSL report # 4921100603, dated 10/13/21, the TVOC level reported was comprised of 11 separate compounds totaling 330 ug/m3. Ethanol was the primary compound 240 ug/m3.
There were no new compounds reported and no unknown compounds.
This was an overall reduction of 72.5% for that 48 hour period.
Reference EMSL report # 492100622 10/15/21, the TVOC level reported was 420 ug/m3 comprised of 16 compounds. *5 new compounds were reported, one unknown compound was also reported.* This day 5 level was an overall reduction of 65.0 % over the 4-day period.
NOTE: No individual compounds reported on day 5 exceeded any established STEL or TLV standards. 420 ug/m3 is an acceptable TVOC level. There are no regulatory standards for TVOC's but 300 to 500 ug/m3 is classified as an acceptable level. Occasional irritation or discomfort may be possible with sensitive persons. (see Addendum A, pg.10)

TVOC and HCHO reading results:

Electrochemical sensor results:

On 10/11/21, the **TVOC** readings in room 203 were reported at an elevated level of 1.28 ppm / 3.83 mg/m3. compared to the outdoor level reported at 0.03 ppm and .33 mg/m3. The indoor hallway at .021 ppm /.33 mg/m3. *This condition in Room 203 would be best described as "strong detectable odor present, irritation or discomfort possible".*

On 10/12/21 after the wall device was installed and filtered fan was operating for about 24 hours, , the levels in Room 203 were reduced to .221 ppm / 1.14 mg/m3. Hallway levels actually increased slightly. Outside levels remained about the same. A reduction of about 70%.

On 10/13/21, the levels in room 203 after more than 48 hours of continuous operation the TVOC was recorded at .021 ppm/.84 mg/m3. A reduction of about 78%.

On 10/14 TVOC levels were further reduced to .021 ppm /.70 mg/m3. Still above the indoor and outdoor control levels. The reduction in room 203 was represented a reduction of about 82% from the initial levels.

By Day 5, 10/15/21, TVOC levels in room 203 were reported at .021 ppm/.32 mg/m3., a reduction of 92%. This level was below the indoor control level.

NOTE: this daily rate of reduction was less than what was reported using ARC and BPI technology in duct mounted and portable devices mfg. by Greentech but similar ending levels achieved.

NOTE: TVOC levels that are below 0.07 ppm are classified as a "no effect " level as it pertains to irritability or discomfort. (see Addendum A, pg.5)

On 10/11/21, the **HCHO** level (formaldehyde) in room 203 was reported at 1.22 mg/m3 compared to .07 mg/m3 in the hallway and .02 mg/m3 outside.

On 10/12/21, with the wall system operating and filtered fan in operation for 24 hours, the HCHO levels in room 203 were reported by the TempTop electrochemical sensors device at .35 mg/m3. A 71% *reduction in 24 hours. Hallway and outside levels had remained about the same.*

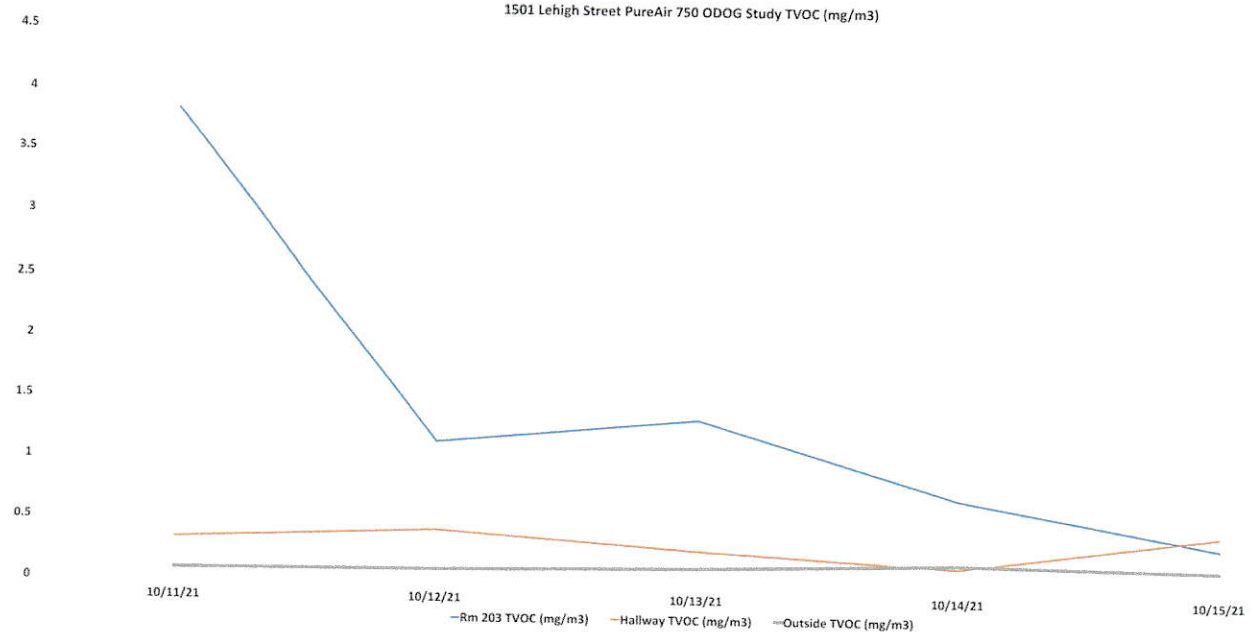
From 10/13 to 10/15, the levels steadily decreased to .07 mg/m3, which on Day 5 was below the indoor control level. This reflected a 94.% reduction using electrochemical sensors.

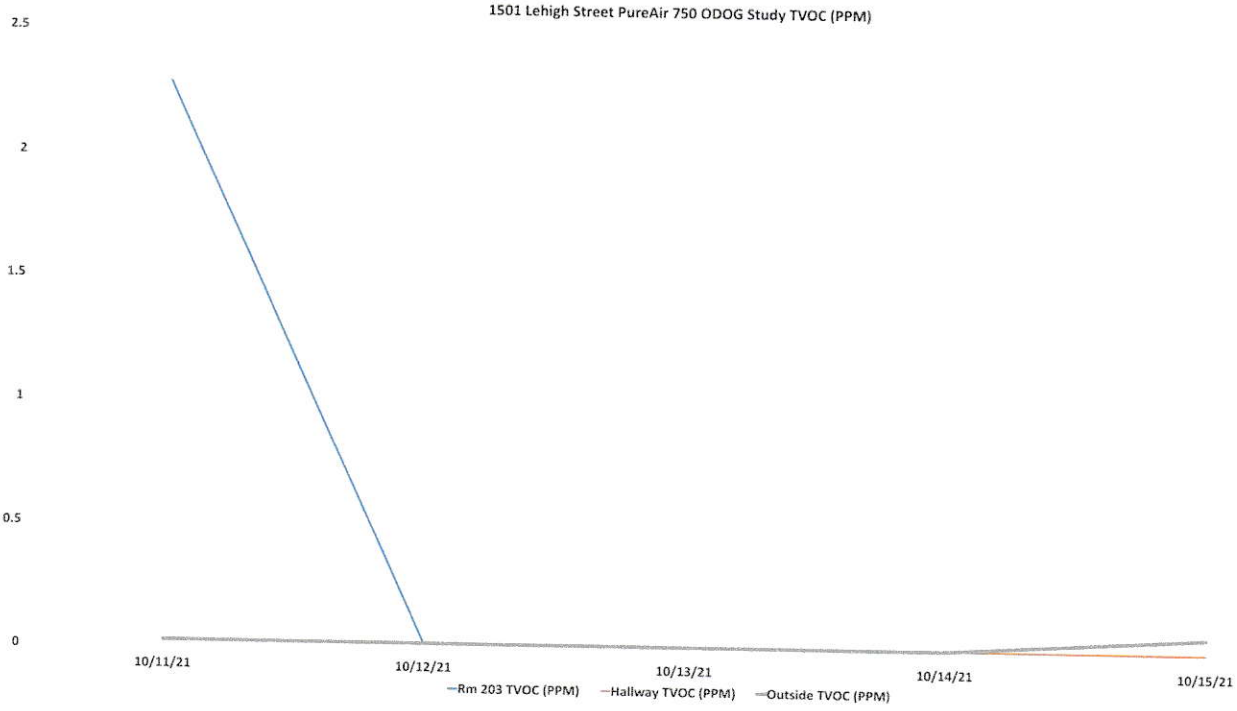
Passive Sampler badge Results:

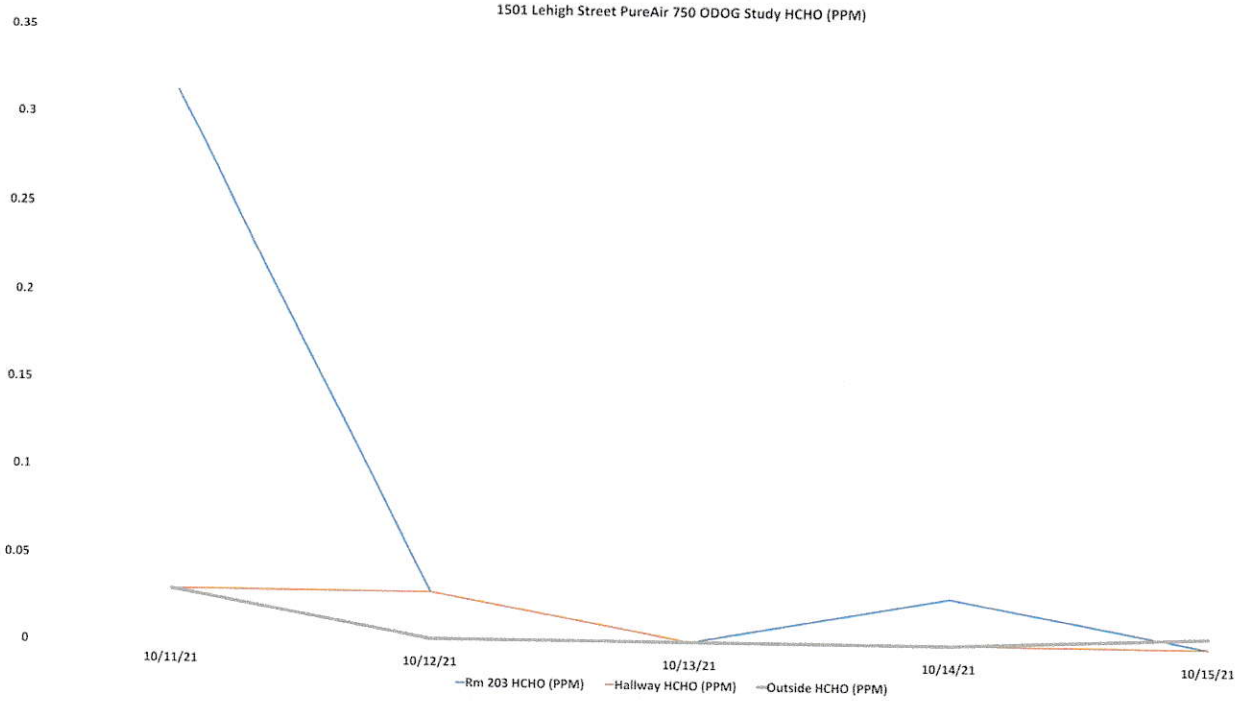
Day 1 - 48.0 ug/m3., 1.7 ppm
Day 2- 48.0 ug/m3, 1.7 ppm
Day 3- 16.0 ug/m3, 0.55 ppm
Day 4- 18.0 ug/m3, 0.55 ppm
Day 5 - 13.0 ug/m3, 0.62 ppm

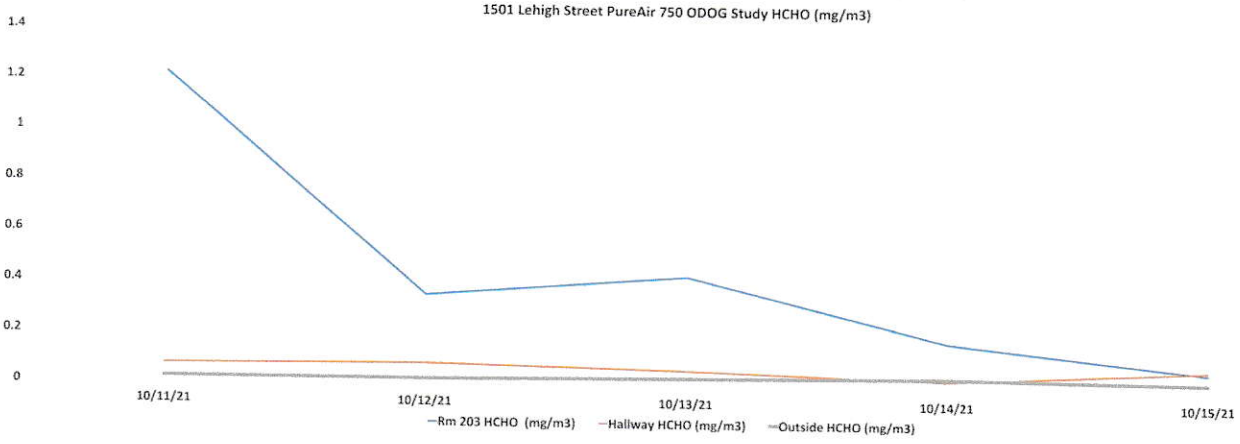
This represented a 64% reduction in Rm. 203 TVOC levels using the passive badge collection method.

NOTE: Natural background levels are < 1 ug/m3 and average .5 ug/m3. Current TLV is 2 ppm. Formaldehyde is quickly photo-oxidized in Carbon Dioxide. It also reacts very quickly with hydroxel radicals to give formic acid. The half life is estimated to be about one hour depending on the environmental conditions.


1501 Lehigh Street PureAir 750 ODOG Study TVOC (mg/m3)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
10/11/21
10/12/21
10/13/21
10/14/21
10/15/21
Rm 203 TVOC (mg/m3)
Hallway TVOC (mg/m3)
Outside TVOC (mg/m3)


1501 Lehigh Street PureAir 750 ODOG Study TVOC (PPM)
2.5
2
1.5
1
0.5
0
10/11/21
10/12/21
10/13/21
10/14/21
10/15/21
Rm 203 TVOC (PPM)
Hallway TVOC (PPM)
Outside TVOC (PPM)


1501 Lehigh Street PureAir 750 ODOG Study HCHO (PPM)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10/11/21
10/12/21
10/13/21
10/14/21
10/15/21
Rm 203 HCHO (PPM)
Hallway HCHO (PPM)
Outside HCHO (PPM)


1501 Lehigh Street PureAir 750 ODOG Study HCHO (mg/m3)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10/11/21
10/12/21
10/13/21
10/14/21
10/15/21
Rm 203 HCHO (mg/m3)
Hallway HCHO (mg/m3)
Outside HCHO (mg/m3)

6. PM 2.5/PM 10.0

On 11 Oct-2021 The PM levels inside Rm. 203 were reported for 2.5PM at 2.4 ug, (micrograms), 10.0 PM at 3.0 ug. Lower than the hallway and outside.

By 12 Oct-2021 the levels inside Rm. 203 had slightly increased to 2.6 and 3.2 respectively. Remaining lower than the inside hallway levels and outside which had also increased a similar amount.

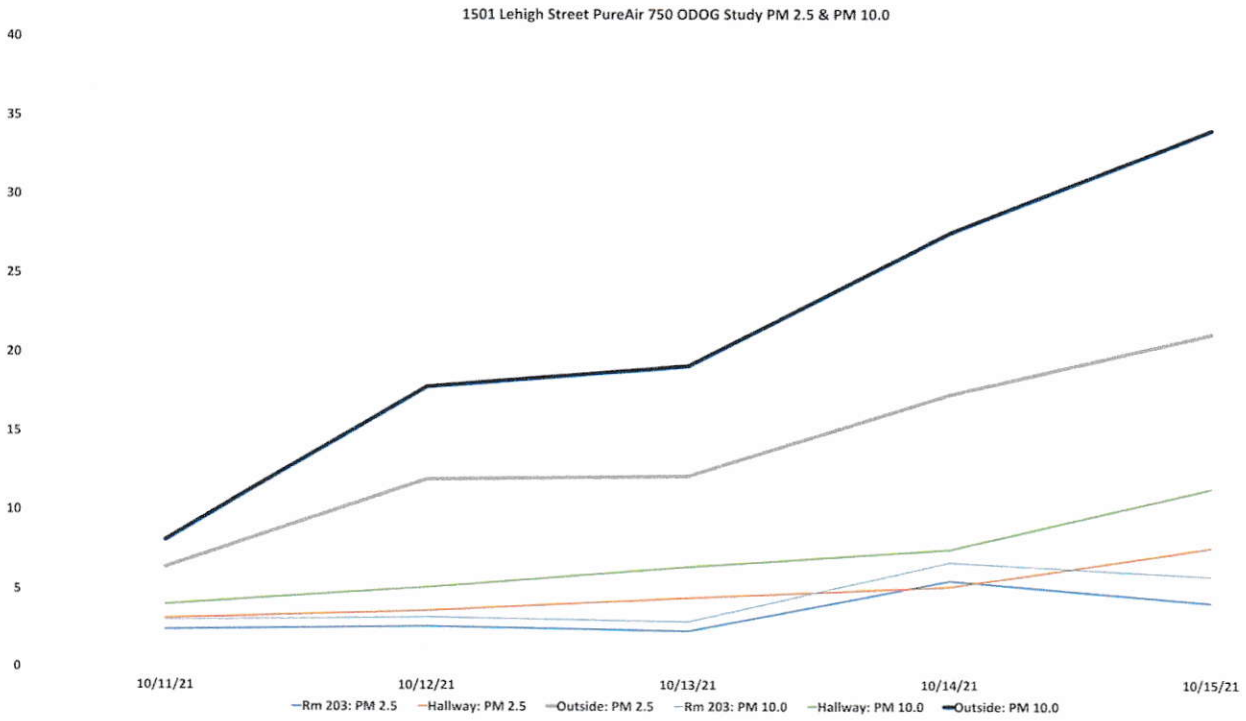
On 10/13/21 the levels decreased to 2.3 and 2.9 while hallway and outside levels significantly increased.

On 10/14/21 the levels nearly doubled from day 3, recorded at 5.5 and 6.7 ug respectively. Hallway and outdoor levels increased also, but at a lesser rate.

On 10/15/21, t**he levels dropped to 4.1 and 5.6 ug respectively, ending higher than the initial levels reported.** Hallway and outdoor levels also increased

OVERVIEW: The PM levels did not appear to be significantly reduced or sustained at lower levels using this combination of abatement devices.

NOTE: The current recommended maximum exposure level to PM2.5 is 15 ug/m3 and PM10.0 at 54 ug/m3.



7. (Respirable) Particle Dust Count Results:

On 10/11/21, the collective total of the 6 particle sizes in room 203 totaled 6,251 micron sized particles, the hallway at 9,351 and outside at 29,158. This level was recorded in a stale air condition with no HVAC or filtered fan operating.

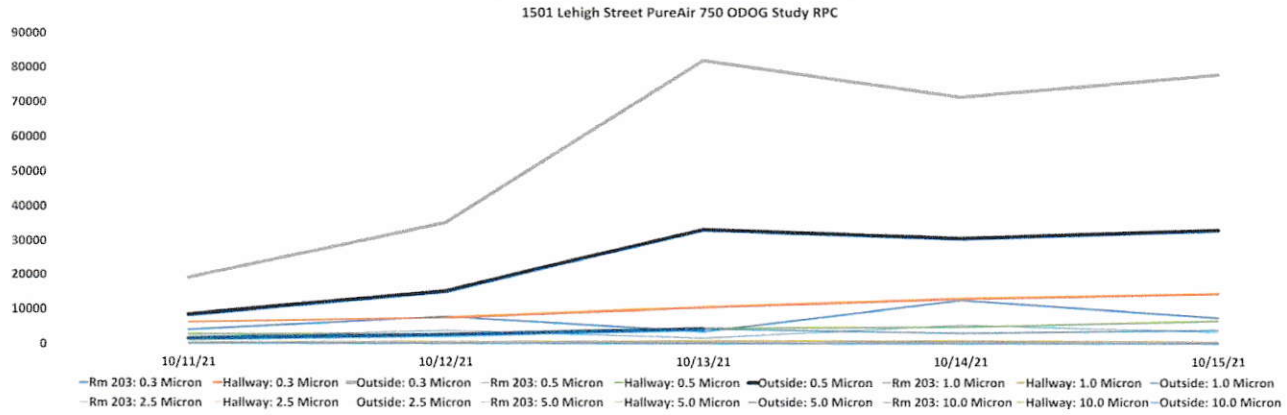
On 10/12/21, with the filtered fan operating, the collective total in room 203 *increased by about 2x, consistent with the increase of the outside levels. The hallway increased by about 12%.*

On 10/13/21 with no HVAC system operating and only the filtered fan operating, the overall RPC in room 203 decreased to 5,336 particles, a reduction of 15% from the initial levels, while the hallway increased by about 50% and the outside more than doubled from the previous day.

On 10/14/21 and 10/15/21, the levels in Room 203 increased significantly and fluctuated up and down. The hallway levels increased steadily over that 2 day period by about 16%. Outside levels remained consistently high between 71,254 and 81,814 particles, increasing by about 10%. The highest RH% recorded during the 5 days was on 10/14/21 at 73.8% when the RPC counts increased by about 3X in Room 203.

The total particle count in Rm 203 did drop below and remain below the hallway levels for those 3 days, but ended higher than the initial levels.

NOTE: The RPC levels in room 203 are classified as low during the 5-day study. The fluctuating results on days 4 and 5 may be resultant from the higher RH% and air turn rate of 5 air turns per hour. The RH% from day 4 to day 5 dropped form 73.8 to 60.8% with a coinciding drop in RPC totals of 39%.



8. Ozone (O3)

Room 203 Levels ranged were recorded at 0.000 ppm. over the 5-day tracking period.
Day 1- 0.000 ppm. inside (Room 203), 0.30 ppm. outside
Day 2- 0.000 ppm. inside, 0.030 ppm outside
Day 3- 0.000 ppm. inside, 0.000 ppm outside
Day 4- 0.000 ppm. inside, 0.028 ppm outside
Day 5- 0.000 ppm. inside, 0.030 ppm outside

NOTE: The current TLV TWA for ozone is 0.1 ppm. Ozone has a 20 minute half life in air.

8. Odor Intensity

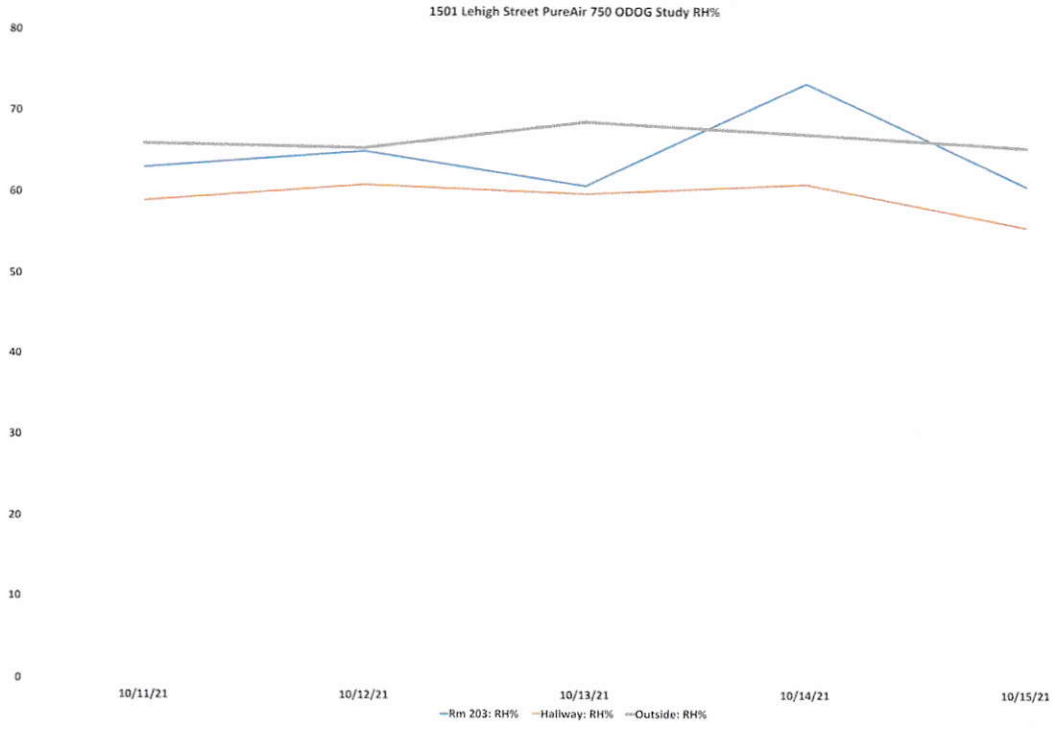
Daily readings were taken for odor intensity using the KANOMAX technology.
Only on Day1 was a reading of 8 registered, the remaining 5 days were at 0.

9. RH%/Temperature

Inside RH% ranged between 60.8% to 73.4% on day 4. *This is higher than the recommended level of 50% for inside environments to minimize airborne virus and disease transmission.*

Inside Temperatures ranged between 66.3 to 72.8 degrees Fahrenheit, within the typical range recommended by ASHRAE.

NOTE: *Indoor RH% at 50% is currently considered the optimum level to still minimize virus and disease transmission.*




1501 Lehigh Street PureAir 750 ODOG Study F° Temp
78
76
74
72
70
68
66
64
62
60
10/11/21
10/12/21
10/13/21
10/14/21
10/15/21
Rm 203: F° Temp
Hallway: F° Temp
Outside: F° Temp

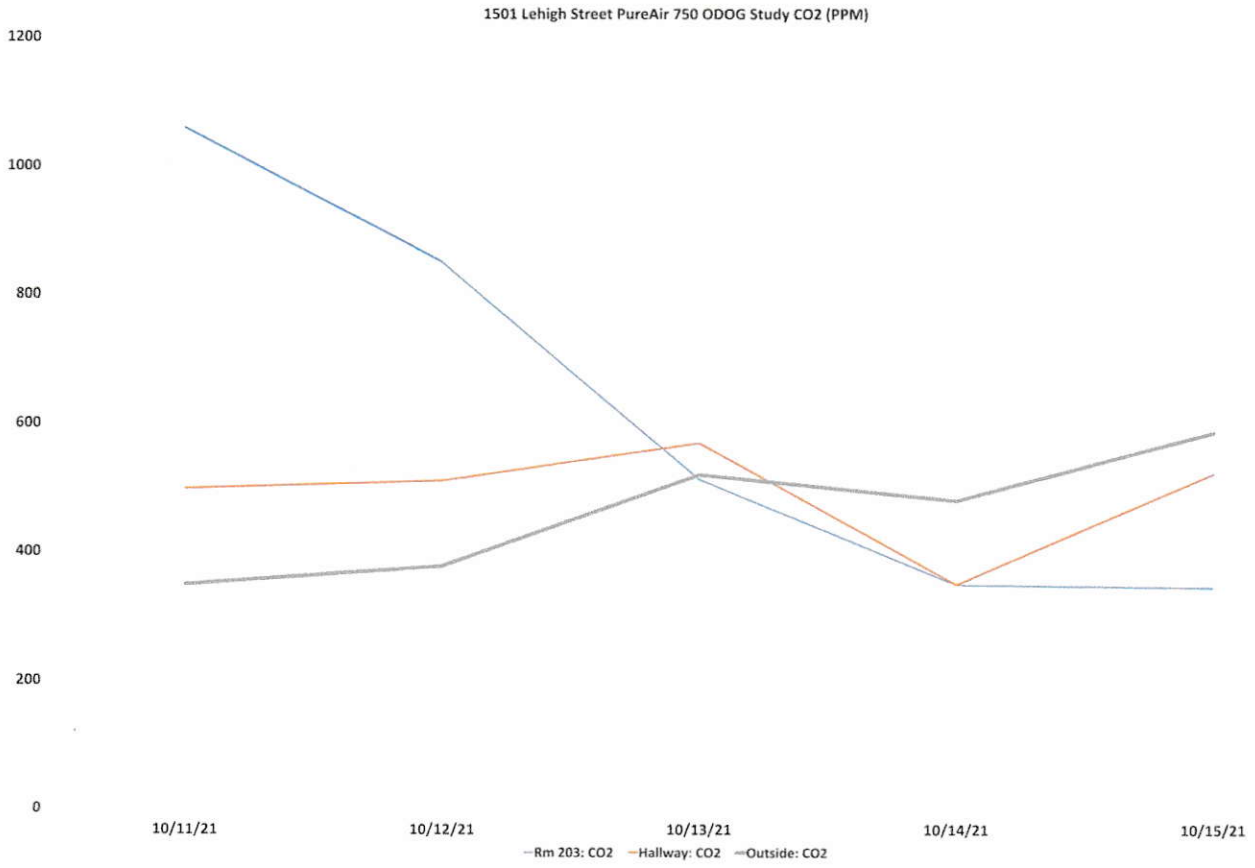
10. Carbon Dioxide- Co2

Room 203 levels on **Day 1** with the stale air condition was recorded at 1059 ppm, untypically high, above the indoor concentration at 497 ppm and outside at 349 ppm.

Day 2 was recorded at 849 ppm, vs 509 ppm and 377 ppm respectively.

From **Day 3 to Day 5**, the indoor concentration steadily decreased to a level below the indoor hallway and outdoor level.

NOTE: The current recommended exposure level to minimize the spread of virus and disease is < 800 ppm. Higher Co2 also serves to increase the photo oxidation process of formaldehyde.



Overview of Results

Preface:

ASHRAE provides guidance in the Epidemic Task Force Filtration and Disinfectant Guide as to the use of supplemental air purification and disinfection equipment after increasing fresh air ventilation rate to a minimum of 6 air changes per hour and filtration levels to a MERV 13 level. This study was performed without those Improvements which will provide a review of efficacy in a commonly found unimproved environment.

Review of Findings

1.	**Mold Spores/ spore trap:**	> 99.% with a MERV 10 filter	4-5% above MERV arrestance level
2.	**Viable Microbials:**		
	Airborne-	mold at > 93% overall reduction	
		Bacteria at 30% reduction overall	
	Surface-	Mold at 95.6% reduction overall	
		Bacteria at 97.0% reduction overall	
3.	**TVOC by T0-15**	65% reduction overall	5 new compounds reported
4.	**TVOC by meter**	92% reduction overall	70% reduction within 24 hours
5.	**HCHO**		
	Electrochemical meter	94% reduction overall	71% within 24 hours
	Passive badge collection	64% reduction overall	
6.	**PM2.5/10.0**	no measurable reduction	no fresh air ventilation
7.	**RPC (airborne particles)**	no sustained reduction	below MERV 13 filtration
8.	**03**	none produced	
9.	**Odor Intensity level**	8 at initial, reduced to 0 within 24 hours	

Indoor Environmental Conditions

RH%- Relative Humidity ranged between 66.8% to 72.8%	higher than the 50% guideline
Temperature- 66.3 to 72.8 degrees F	within recommended guidelines
C02- carbon dioxide – initial @ 1059 ppm	stale air condition for 48 hours
Day 2 @ 849 ppm	
Day 3-5 345 to 512 ppm	normal, below outside levels

It is my considered Opinion that……
If this unit was used within the current guidelines set for ventilation and filtration increased abatement of the tested contaminants and even greater overall efficacy could be expected.

Authorized Signature
Keith Roe CIE/CMC
Date submitted: 10/29/21

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Addendum A:

SPORE TRAP METHOD

Using a cassette sampler, a 75L/5 minute or 150L/10-minute air sample was taken in each designated location. This "spore-trap" device will capture airborne particulates on a sticky surface inside a sealed cassette. A certified microbiologist then opens this cassette in a lab environment. The particulate matter is then identified into seven separate categories and quantified as to air concentration level.

Category	Quantifiable Method
➢ Mold Spores (live and dead)	Spore Count/M^3
➢ Hyphae fragment (mold parts)	S/M^3 (1)
➢ Pollen	S/M^3
➢ Background dust	S/M^3

(1) Particle count per cubic meter of air.

These indoor levels are then compared to the outside baseline level as well as current guidelines cited in this report.

Type of Sample	Low Levels of Fungal Contamination	Elevated levels of Fungal Contamination
Spore Trap Samples (Air-o-cell, Micro5)	<1,000 Spores/M^3 of air	>2,000 Spores/M^3 of air

It should be noted that identification of the cassette is based on the spore alone. This procedure is presumptive, and the viability of the spores is unknown. It should also be noted that these samples were "grab samples" as opposed to continuous samples, and as such, their data should be viewed as a snapshot of conditions that existed at the time of this inspection and sampling. Since isolated release events of fungi can cause the results to be skewed in either direction, caution should be used in interpreting grab sample results. The alternative to this sampling is semi-continuous sampling. Due to the extreme cost of this sampling method, it is generally reserved for conditions where clinical signs or symptoms of disease have been established and a cause is being sought.

It should also be noted that there are no standards for measuring indoor air quality. The ACGIH Bioaerosols Committee recommends sampling in complaint, non-complaint, and outdoor areas several times during the day and making comparisons between the areas. Since the purpose of this investigation was to conduct an indoor air quality screening, and not to provide an in-depth microbiological assessment, our procedures differentiated from the ACGIH recommendations in that only one sample was collected from each of the subject areas during the day.

Note: Bioaerosol testing is a "snapshot" of conditions present on the test date. Indoor Air Quality (IAQ) is affected by occupancy, indoor and outdoor temperature and relative humidity, water infiltration, outdoor air infiltration and many other factors. The test results were an indication of conditions identified on the test date. At any point in time, these conditions may change and impact future test results.

INTERPRETATION OF THE LAB REPORTS

This is <u>not</u> a health risk assessment or interpretation. This interpretation is provided for initial site assessment and development of a site improvement or remediation plan. All testing results <u>must</u> be shared with your physician or allergists for interpretation as to potential health impact or concern.

BIOAEROSOLS

Bioaerosols are those airborne particles that are living or originate from living organisms. Bioaerosols include microorganisms (i.e., culturable, nonculturable and dead microorganisms) and fragments, toxins and particulate waste products from all varieties of living things. Bioaerosols are ubiquitous in nature and may be modified by human activities. All persons are repeatedly exposed, day after day, to a wide variety of such materials. Individual bioaerosols range in size from submicroscopic particles (<0.01um) to particles greater than 100um in diameter.

Almost all air in indoor environments contain microorganisms. Environmental factors that influence indoor microbial concentrations include outdoor concentrations, type and rate of ventilation and indoor moisture levels. Airborne microbial concentrations in indoor environments also vary with the amount of mechanical and/or human activity. A large number of people and/or abundant activity stirs up dust (dispersing settled spores into the air) and creates air currents, delaying deposition by gravity. In addition, fungal spores can be introduced when people enter the area, either on people themselves or on clothing.

Molds can be found almost anywhere; they can grow on virtually any organic substance, as long as, moisture and oxygen are present. There are molds that can grow on wood, paper, carpets, foods and insulation. When excessive moisture accumulates in buildings or on building materials, mold growth will often occur, particularly if the moisture problem remains undiscovered or unaddressed. It is possible to eliminate all mold and mold spores in the indoor environment. However, mold growth can be controlled indoors by controlling moisture indoors.

MICROORGANISMS

Microorganisms are a normal and essential component of all environments. Bacteria and fungi are needed to break down complex molecules found in organic matter. If provided with water and a food source, they will colonize almost any area on Earth. Microorganisms and/or their reproductive structures are almost always found in outdoor air. Their types and populations will vary depending on local environmental conditions. Doors, windows, and fresh air intakes provide easy access for microorganisms to enter the interiors of buildings.

It is normal to find some quantity of microorganisms in indoor air. In a normal indoor environment, their numbers should be significantly less than outdoor levels. Excessive moisture inside a building from leaks, floods, or other sources can create an "out-of-balance" environment that will tend to amplify their population. Depending on the amount of water, temperature, lighting, and food available, differing species may become dominant. In consequence, the presence of some microorganisms in large quantities may lead to adverse health effects involving building occupants.

Adverse health effects in affected individuals can include both illnesses and allergic responses. Symptoms may range from headache, malaise, and muscle pain to shortness of breath and fever. These effects may be the result of contact with the microbes or spores themselves, or with contracting the airborne toxins that they may excrete. **Test results and health concerns should be shared with your physician for the best and most accurate interpretation.** They are best used to help visualize the potential for problems.

AIRBORNE MICROBIAL TESTING

Premise...

Bioaerosols are those airborne particles that are living or originate from living organism. Bioaerosols include microorganisms (i.e., culturable, nonculturable, and dead microorganisms) and fragments, toxins, and particulate waste products from all varieties of living things. Bioaerosols are ubiquitous in nature and may be modified by human activities. All persons are repeatedly exposed, day after day, to a wide variety of such materials. Individual bioaerosols range in size from submicroscopic particles (<0.01 µm) to particles greater than 100 µm in diameter.

Almost all air in indoor environments contains microorganisms. Environmental factors that influence indoor microbial concentrations include outdoor concentrations, type and rate of ventilation, and indoor moisture levels. Airborne microbial concentrations in indoor environments also vary with the amount of mechanical and/or human activity. A large number of people and/or abundant activity stirs up dust (dispersing settled spores into the air) and creates air currents, delaying deposition by gravity. In addition, fungal spores can be introduced when people enter the area, either on people themselves or on clothing.

Common substrates in the indoor environment serve as nutrient sources for saprobic and/or opportunistic pathogens and allow for growth and continued spore formation indoors. The most familiar indoor substrates include carpets (especially those with jute or other natural backings), components of upholstered furniture, and soap film on shower walls, shower curtains, bathroom fixtures, wallpaper, water and scale in humidifiers, and soil and surfaces of containers for potted plants. Air Handling Units (AHUs) can also serve as amplification and dissemination sites for fungal spores. Fungi have been found growing on air filters, cooling coils, and drip pans, as well as in ducts. Routine filter, drip pan maintenance, and control of relative humidity will usually prevent or minimize problems associated with moisture.

PARTICLE IMPACTOR SAMPLING – VIABLE MOLD AND BACTERIA ANALYSIS

This method of air sampling involves drawing a measured volume of air over culture media in Petri dishes. These dishes are incubated in a certified microbiological laboratory so the organisms impacted on the plate can grow. The fungi or bacteria are counted and identified by genus and species.

BENEFITS

1. Fungal cultures can determine whether spores are viable (alive) and allows for specific identification by species.
2. Bacterial cultures provide enumeration and identification of viable bacteria present in the air.

From these culture results, airborne concentrations of viable microbial spores can be projected indicating CFU/M³ (Colony Forming Units per cubic meter of air).

SWAB SAMPLING METHODS

Surface sampling of the "suspect growth" will allow the lab to culture the microbial (mold, yeast, bacteria) as a viable micro-organism calculating CFU/IN^2 (Colony Forming Units per sq. in.). These viable colonies produce spores that can be identified by genus and individual species allowing classification of the micro-organism as allergenic, mycotoxic, pathogenic, or other health concern.

Swab sampling of surfaces was done using BBL Culturettes with Stuart's transport medium. Swabs were used wet or dry, as required for each sample site.

Swabs were aseptically transferred to 5 mL of TAT broth/diluent, vortexed for one minute, ultrasonicated for one minute, vortexed again for one minute and 0.1mL spread plates prepared on Malt Extract Agar (MEA) and Cornmeal Agar (CMA) for fungal growth and Tryptic Soy Agar (TSA) for bacterial growth. All mold colony types were identified to at least genus.

OUTSIDE CONTROL

Principle: An outdoor sample of the same volume is taken on the same medium type to serve for comparison with the results of inside sample readings. If the numbers and types of any organisms recovered inside significantly exceed those found outdoors, a condition of fungal amplification is then confirmed as occurring within the building.

VOLATILE ORGANIC COMPOUNDS

Application

Volatile Organic Compounds (VOCs) are carbon and hydrogen bonded compounds that have atomic masses between 40 and 500 amu, can easily evaporate at room temperature and enter the atmosphere under normal conditions as a gas. Generally, VOCs are chemicals that have boiling ranges from 50 to 260° Celsius, with a few exceptions. There is no common chemical structure for VOCs; they can range from short carbon chains to more complex aromatic rings.

Paints, paint stripper, air fresheners, inks, stored fuel or other solvents, cleaning supplies, new carpets, cosmetics, dry-cleaned clothing, vehicle exhaust, and lawn mowers all contribute to indoor VOC emissions. Health effects can range from dizziness, headaches, blurred vision, nausea, eye and throat irritation to cancer and even death. Health effects are directly related to levels and duration of exposure. The most common route of exposure to VOCs is through inhalation.

Levels of Concern:

A recent study addressed the relationship between low-level VOC exposure and human health. The study established epidemiological and biological models of human responses so that it could compare the results of numerous field investigation and controlled experiments conducted over several years. The study reached the following conclusions:

The "no effect" level is about 0.07 PPM. A multifactorial exposure range exists from 0.07 to 1 PPM in which odor, irritation, and discomfort may appear as a consequence of VOC exposure or other exposures (temperature, humidity, etc.) contribute to the etiology. Effects are always expected above 1 PPM and irritation symptoms have been documented at 1.7 PPM in controlled experiments.

Tentative Dose Response Relationship for Exposure to VOC's	
Total Concentration VOC's (PPM)	***Irritation and Discomfort***
<0.07	No irritation or discomfort
0.07 – 1.0	Odor, irritation, and discomfort possible if other exposures interact
1.0 – 8.5	Irritation exposure effects probable and headache possible if other exposures interact
>8.5	Additional neurotoxic effects other than headache may occur

IAQS ADVANCED IAQ SOLUTIONS, INC
630 Trach Rd.
Bath, PA 18014

EPA COMPENDIUM TO-15

1. Scope

1.1 This method documents sampling and analytical procedures for the measurement of the 97 volatile organic compounds (VOC's) that are included in the 189 hazardous air pollutants (HAPS) listed in Title III of the Clean Air Act of 1990. VOC's are defined here as organic compounds having a vapor pressure greater than 10^{-1} Torr at 25°C and 760 MmHg.

2.1 The atmosphere is sampled by introduction of air into a specially prepared stainless steel canister. A sample of air is drawn through a sampling train comprised of components that regulate the rate and duration of sampling into the pre-evacuated and passivated canister.

3.1 To analyze the sample, a known volume of sample air is directed from the canister through a solid multisorbent concentrator. A portion of the water vapor in the sample breaks through the concentrator during sampling, to a degree depending on the multisorbent composition, duration of sampling and other factors. Water content of the sample can be further reduced by dry purging the concentrator with helium while retaining target compounds. The VOC's are thermally desorbed, entrained in a carrier gas stream, and then focused in a small volume. The sample is then released by thermal desorption and carried onto a gas chromatographic column for separation.

4.1 Each compound is identified by CAS number and reported quantitatively as to content in the ambient air by ppbv (parts per billion by volume) and ug/m3 (micrograms per cubic meter of air). This is compared to the federally established standard for human exposure.

From Compendium Method TO-15: Determination Of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed By Gas Chromatography / Mass Spectrometry (GC/MS):

http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-15r.pdf

1. Scope

1.1 This method documents sampling and analytical procedures for the measurement of subsets of the 97 volatile organic compounds (VOCs) that are included in the 189 hazardous air pollutants (HAPs) listed in Title III of the Clean Air Act Amendments of 1990...Table 1 is the list of the target VOCs along with their CAS number, boiling point, vapor pressure ...This method applies to ambient concentrations of VOCs above 0.5 ppbv and typically requires VOC enrichment by concentrating up to one liter of a sample volume. The VOC concentration range for ambient air in many cases includes the concentration at which continuous exposure over a lifetime is estimated to constitute a 10-6 or higher lifetime risk of developing cancer in humans. Under circumstances in which many hazardous VOCs are present at 10-6 risk concentrations; the total risk may be significantly greater...

2. Summary of Method

2.1 The atmosphere is sampled by introduction of air into a specially-prepared stainless steel canister... A sample of air is drawn through a sampling train comprised of components that regulate the rate and duration of sampling into the pre-evacuated and passivated canister... After the air sample is collected, the canister valve is closed; an identification tag is attached to the canister, and the canister is transported to the laboratory for analysis...

2.4 To analyze the sample, a known volume of sample is directed from the canister through a solid multi-sorbent concentrator. After the concentration and drying steps are completed, the VOCs are thermally desorbed, entrained in a carrier gas stream, and then focused in a small volume by trapping on a reduced temperature trap or small volume multi-sorbent trap. The sample is then released by thermal desorption and carried onto a gas chromatographic column for separation...

2.5 The analytical strategy for Compendium Method TO-15 involves using a high resolution gas chromatograph (GC) coupled to a mass spectrometer... Mass spectra for individual peaks in the total ion chromatogram are examined with respect to the fragmentation pattern of ions corresponding to various VOCs including the intensity of primary and secondary ions. The fragmentation pattern is compared with stored spectra taken under similar conditions, in order to identify the compound. For any given compound, the intensity of the primary fragment is compared with the system response to the primary fragment for known amounts of the compound. This establishes the compound concentration that exists in the sample.

Mass spectrometry is considered a more definitive identification technique than single specific detectors such as flame ionization detector (FID), electron capture detector (ECD), photoionization detector (PID), or a multidetector arrangement of these (see discussion in Compendium Method TO-14A). The use of both gas chromatographic retention time and the generally unique mass fragmentation patterns reduce the chances for misidentification. If the technique is supported by a comprehensive mass spectral database and a knowledgeable operator, then the correct identification and quantification of VOCs is further enhanced.

EVALUATION FACTORS FOR AIRBORNE FUNGAL SPORES

A combination of the following factors, derived from professional groups such as ACGIH (American Conference of Government and Industrial Hygienists), other professionals in the field and the investigator's experience, is used to aid in determining if airborne fungi levels might be higher than desirable or might be pointing to one or more growth reservoirs in the building:

1. For total fungal spore counts (cumulative count of all groups in a sample), total counts for each type of fungus in a sample and total counts of other fungal structures in a sample, indoor levels should be less than outdoor levels are atypical (e.g. low during outdoor snow cover).

2. There should be no *significant difference (presence) of the following indicator or marker organism groups for potential mold and moisture sources inside the work area:

Aureobasidium	Aspergillus
Chaetomium	Fusarium
Penicillium	Trichoderma
Ulocladium	Cladosporium

*Significant difference (presence), also referred to as amplification, is defined as a factor of 120% as used to compare total counts of fungal spores and structures inside and outside of a building (i.e. 1.2 times higher inside than outside constitutes significant presence of amplification). Indoor levels of individual water damage indicator mold types should be below 250 S/M^3.

3. In general, total spore concentrations for indoor airborne samples should be less than 300 – 400 Colony Forming Units per cubic meter (CFU/m3), Higher total concentrations should be acceptable if they are similar to or less than total outdoor total counts and indoor groups are the same as outdoor groups and are present in indoor samples in similar or lesser concentrations relative to the same groups in outdoor samples.

4. There shall be no presence of the following group inside the building:

Stachybotris

MERV RATING CHART

Standard 52.5 Minimum Efficiency Reporting Value	Dust Spot Efficiency	Arrestance	Typical Controlled Contaminant	Typical Applications and Limitations	Typical Air Filter/Cleaner Type
20	n/a	n/a	< 0.30 pm particle size	Cleanrooms	>99.999% eff. On .10-.20 pm Particles
19	n/a	n/a	Virus (unattached)	Radioactive Materials	Particles
18	n/a	n/a	Carbon Dust	Pharmaceutical Man.	Particulates
17	n/a	n/a	All Combustion smoke	Carcinogenetic Materials	>99.97% eff. On .30 pm Particles
16	n/a	n/a	.30-1.0 pm Particle Size	General Surgery	**Bag Filter-** Nonsupported
15	>95%	n/a	All Bacteria	Hospital Inpatient Care	microfine fiberglass or synthetic media, 12-36 in. deep, 6-12 pockets
14	90-95%	>98%	Most Tobacco Smoke	Smoking Lounges	**Box Filter-** Rigid Style Cartridge Filters 6 to 12" deep m ay use lofted or paper media.
13	89-90%	>98%	Proplet Nuceli (Sneeze)	Superior Commercial Buildings	
12	70-75%	>95%	1.0-3.0 pm Particle Size Legionella	Superior Residential	**Bag Filter-** Nonsupported
11	60-65%	>95%	Humidifier Dust Lead Dust	Better Commercial Buildings	microfine fiberglass or synthetic media, 12-36 in. deep, 6-12 pockets
10	50-55%	>95%	Milled Flour Auto Emissions	Hospital Laboratories	**Box Filter-** Rigid Style Cartridge Filters 6 to 12" deep m ay use lofted or paper media.
9	40-45%	>90%	Welding Fumes		
8	30-35%	>90%	3.0-10.0 pm Particle Size Mold Spores	Commercial Buildings	**Pleated Filters-** Disposable, extended surface area, thick with cotton-polyester blend media, cardboard frame
7	25-30%	>90%	Hair Spray Fabric Protector	Better Residential	**Cartridge Filters-** Graded density viscous coated cube or pocket filters, synthetic media
6	<20%	85-90%	Dusting Aids Cement Dust	Industrial Workplace	**Throwaway-** Disposable synthetic panel filter.
5	<20%	80-85%	Pudding Mix	Paint Booth Inlet	
4	<20%	75-80%	>10.0 pm Particle Size Pollen	Minimal Filtration	**Throwaway-** Disposable fiberglass or synthetic panel filter.
3	<20%	70-75%	Dust Mites Sanding Dust	Residential	**Washable-** Aluminum Mesh
2	<20%	65-70%	Spray Paint Dust Textile Fibers	Window A/C Units	**Electrostatic-** Self charging woven panel filter.
1	<20%	<65%	Carpet Fibers		

TVOC

Total Volatile Organic Compunds

The Total Volatile Organic Compound (TVOC) level is a measurement of the sum of all of the volatile organic compounds (VOC's) found in an air sample. The TVOC is an important indication of the overall air quality in a building because there has been so much information on the TVOC levels collected over the years, and using this data scientists have been able to put together the table shown below that provide a good indication of the overall indoor air quality.

It is important to also measure the individual VOC compounds in order to understand what is contributing to the TVOC if it is high, so action can be taken to reduce exposure and the TVOC level.

The TVOC level does not distinguish between chemicals that may be toxic and those that are not, so in addition to looking at the TVOC levels, the levels of the individual chemicals found in the air sample should be evaluated.

There are no regulatory standards for TVOC's so these levels should serve as a guideline

TVOC Level ug/m3	Level of Concern	Symptoms	Comments
Less than 300	Low	No irritation or discomfort is expected.	There is a low likelihood that specific VOC sources are present
300 to 500	Acceptable	Occasional irritation or discomfort may be possible with sensitive individuals.	There is a low to moderate likelihood that specific VOC sources are present
500 to 1000	Marginal	Complaints about irritation and discomfort are possible in sensitive individuals	A moderate likelihood that specific VOC sources are it is recommended that steps be taken to identify the sources
1000 to 3000	High	Irritation and discomfort are very likely	A high likelihood that specific VOC sources are present and it is highly recommended that steps be taken to identify them.
More than 3000	Very High	Irritation and discomfort are very possible.	These levels are usually found in an industrial environment where workers are exposed to chemicals

FORMALDEHYDE 2016

$H_2C=O$ MW: 30.03 CAS: 50-00-0 RTECS: LP8925000

METHOD: 2016, Issue 2 **EVALUATION:** FULL **Issue 1: 15 January 1998**
Issue 2: 15 March 2003

OSHA: 0.75 ppm; 2 ppm STEL
NIOSH: 0.016 ppm; C 0.1 ppm; carcinogen
ACGIH: C 0.3 ppm; suspected human carcinogen
(1 ppm = 1.23 mg/m³ @ NTP)

PROPERTIES: Gas; BP -19.5 °C; specific gravity 1.067 (air = 1); explosive range 7 to 73% (v/v) in air

NAMES & SYNONYMS: methanal; formalin (aqueous 30 to 60% w/v formaldehyde); methylene oxide

SAMPLING

SAMPLER: CARTRIDGE
(Cartridge containing silica gel coated with 2,4-dinitrophenylhydrazine)

FLOW RATE: 0.03 to 1.5 L/min

VOL-MIN: 1 L @ 0.25 mg/m³
-MAX: 15 L @ 2.5 mg/m³

SHIPMENT: Place caps onto cartridge. Ship on ice.

SAMPLE STABILITY: 34 days @ 5 °C [1]

BLANKS: 2 to 10 field blanks per set
6 to 10 media blanks per set

ACCURACY

RANGE STUDIED: 0.025 to 2.45 mg/m³ (22-L samples) [2]

BIAS: +4.4%

OVERALL PRECISION ($\hat{S}_{r,T}$): 0.057 [1,2]

ACCURACY: ±19.0%

MEASUREMENT

TECHNIQUE: HPLC, UV DETECTION

ANALYTE: 2,4-dinitrophenylhydrazone of formaldehyde

EXTRACTION: Elution with 10 mL of carbonyl-free acetonitrile

INJECTION VOLUME: 20 µL

MOBILE PHASE: 45% acetonitrile/55% water (v/v), 1.3 mL/min

COLUMN: 3.9 x 150-mm, stainless steel, packed with 5-µm C-18, Symmetry™ or equivalent

DETECTOR: UV @ 360 nm

CALIBRATION: Samplers fortified with standard solutions of formaldehyde in water

RANGE: 0.23 to 37 µg per sample [1,2]

ESTIMATED LOD: 0.07 µg/sample [1]

PRECISION ($\hat{S}_r$): 0.032 @ 1.0 to 20.0 µg/sample [1]

APPLICABILITY: The working range is 0.015 to 2.5 mg/m³ (0.012 to 2.0 ppm) for a 15-L sample. This method can be used for the determination of formaldehyde for both STEL and TWA exposures [1,2].

INTERFERENCES: Ozone has been observed to consume the 2,4-dinitrophenylhydrazine (2,4-DNPH) reagent and to degrade the formaldehyde derivative [3]. Ketones and other aldehydes can react with 2,4-DNPH; the derivatives produced, however, are separated chromatographically from the formaldehyde derivative.

OTHER METHODS: NIOSH methods 2541 [4] and 3500 [5] and OSHA method 52 [6] are other methods for determination of formaldehyde in air. NIOSH method 5700 employs 2,4-DNPH and HPLC for determination of formaldehyde on textile or wood dust [7]. A journal method employs the same procedure for formaldehyde in automobile exhaust [8].