THE CAMFIL GROUP

Air Filtration in Cannabis Cultivation

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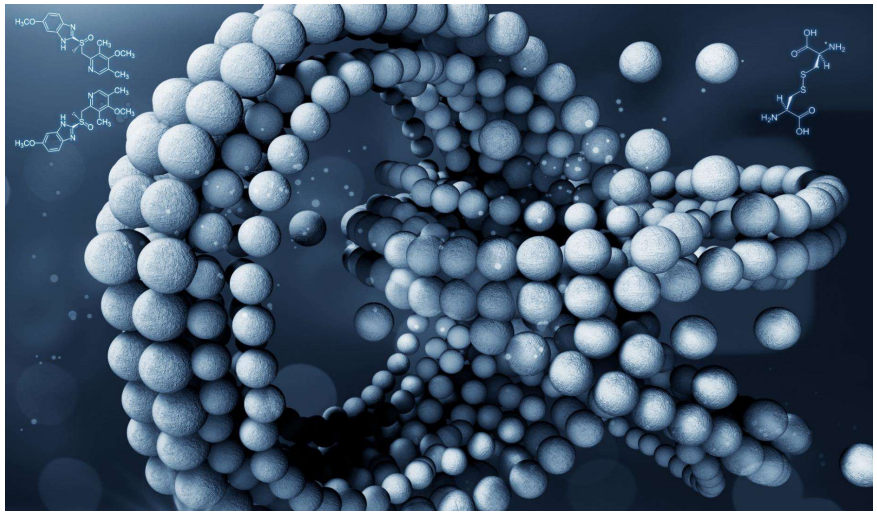
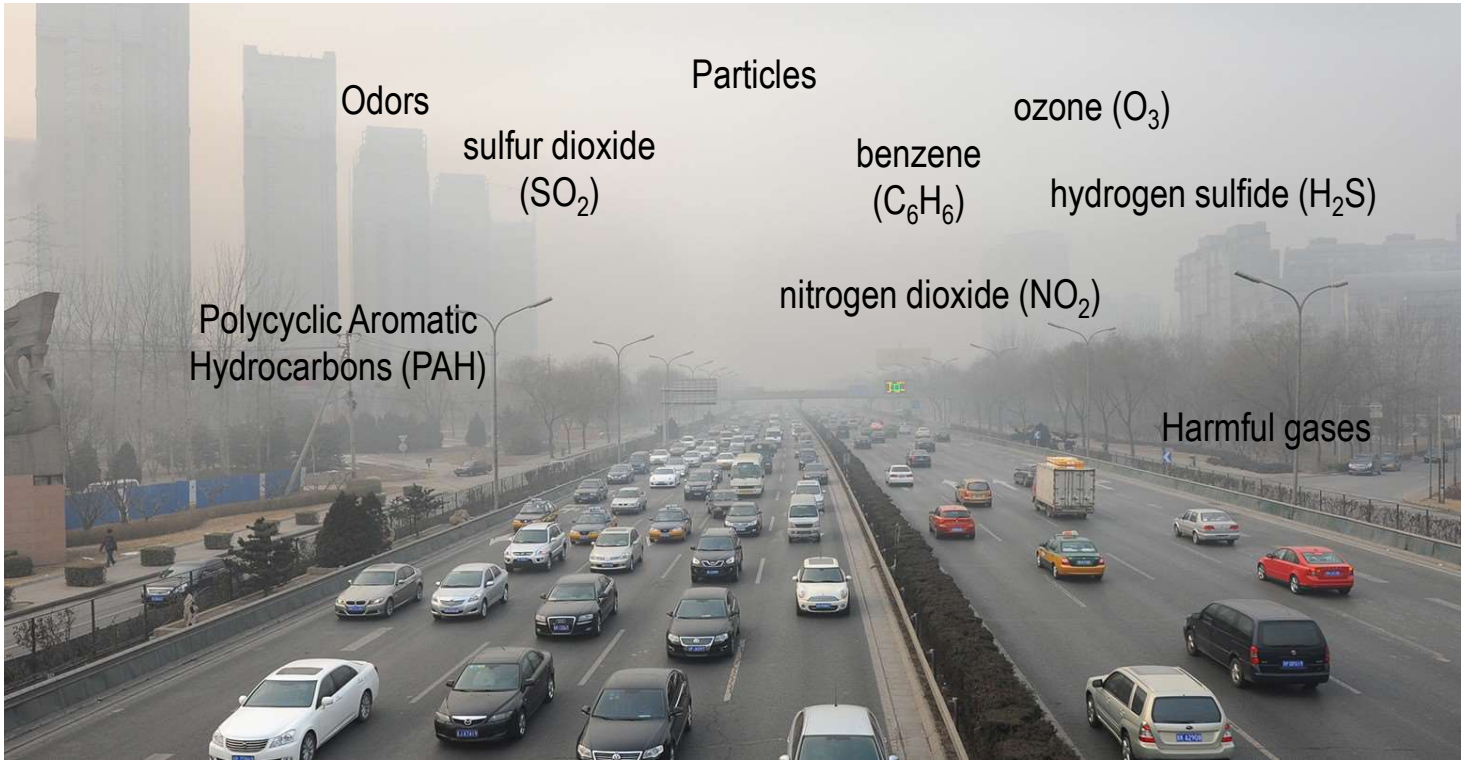
INTRODUCTION TO MOLECULAR FILTRATION

- Principals
- Recognized media types deployed in molecular filtration
- Recognized standards
- Focus application-Cannabis Cultivation

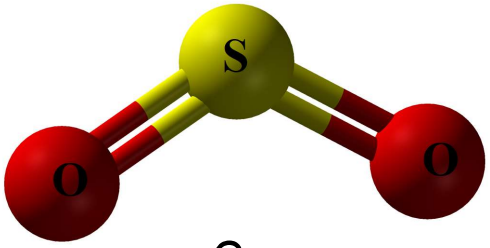


WHAT IS IN THE AIR?



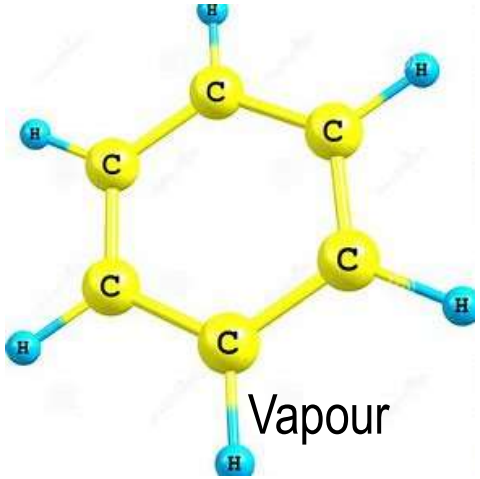
WHAT IS MOLECULAR POLLUTION

- Molecules e.g. of harmful gasses or vapours
- Molecules are NOT removed by particle filtration (not even HEPA / ULPA)



Gas

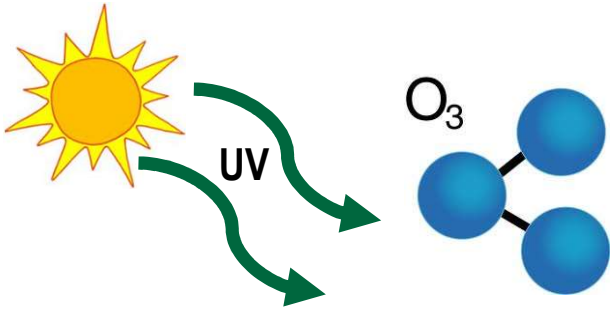
Sulfur Dioxide, SO2, B.P: -10



Vapour

Benzene, C6H6, B.P:80.1

EXTERNAL SOURCE OF MOLECULAR POLLUTANTS



Gas	Source	Typical City Concentration (USA)	Health Guidelines
Nitrogen dioxide	Vehicle emissions	20 – 60 µg/m^3 (long term)	WHO 40 µg/m^3 1 year average, 200 µg/m^3 1 hour average.
BTEX	Vehicle emissions		Benzene, toluene, ethyl benzene, xylene (hydrocarbons)
Sulfur dioxide	Combustion processes	15 – 30 µg/m^3	WHO 20 µg/m^3 24 hour average, 500 µg/m^3 10 minute average
Ozone	Atmospheric pollution +UV	100 – 200 µg/m^3	WHO 100 µg/m^3 8 hour average,

INTERNAL SOURCE OF MOLECULAR POLLUTANTS

IAQ and Comfort application:

- 100 or 1,000 of VOCs
- (Volatile Organic Compounds)
- Some chemicals are known, most are not
- Individually, concentrations are low
- What about the cocktail effect?
- Very expensive to measure

INTERNAL SOURCE OF MOLECULAR POLLUTANTS
Industrial application:

- contaminants that are in the space are much more specific
- concentrations or usage rates are known

EFFECTS OF MOLECULAR POLLUTANTS

Smell / Odour (nuisance)

- *Cooking smells*
- *Waste water treatment*
- *Cannabis cultivation*
- *Aviation fuel*

Irritants (health effects)

- *Ozone*
- *Nitrogen dioxide*
- *Ammonia*
- *Paint Solvents*

Poison / Toxin (possible fatalities)

- *War Gases*
- *Hydrogen cyanide*
- *Isocyanates*
- *Dioxins*
- *Radioactive isotopes*

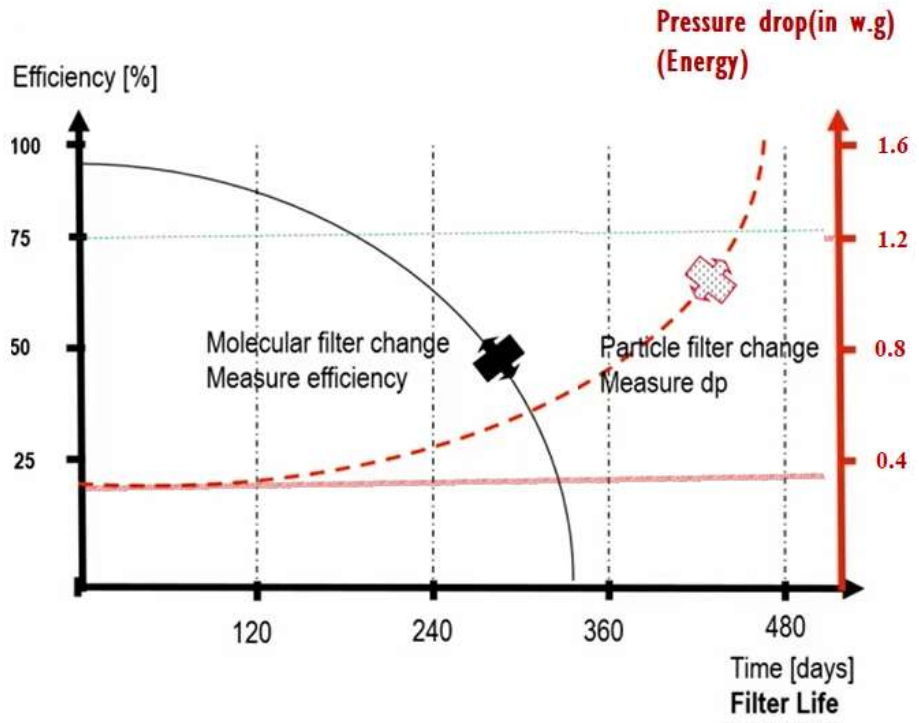
Corrosion (failures)

- *Acidic gases in paper mills*
- *Acidic gases in petrochemical refineries*
- *Reactive gases in museums*
- *Acidic gases in semi-conductor fabs*

HOW TO REMOVE MOLECULES FROM THE AIR?

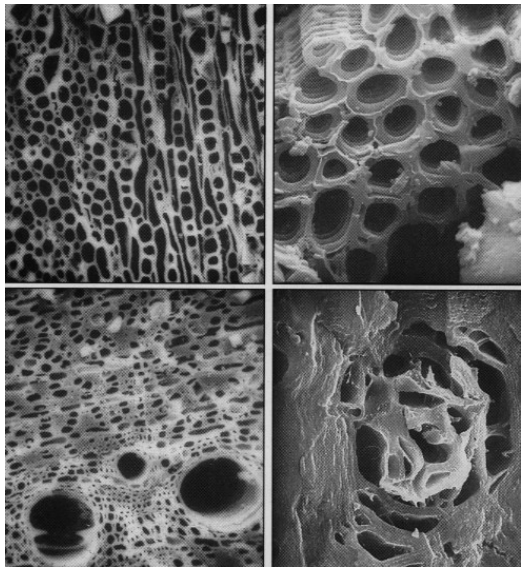
- Molecules are 1,000-10,000 times smaller than fine particles (PM1).
- There are tens of millions of particles in 1 cubic foot of city air.
- The number of molecules is many orders of magnitude higher than the number of particles.
- Particle filters will not remove molecules, we need to do something different…..
- We exploit a technique called adsorption.
- We mostly use activated carbon, activated alumina and ion exchange resin.

HOW DO MOLECULAR FILTERS WORK



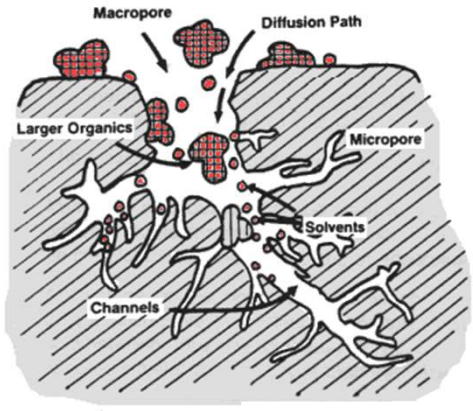
HOW DO MOLECULAR FILTERS WORK?

- All adsorbents are porous – structure is full of very small holes.



- Very high internal surface area values.
  - *Activated carbon: > 10,000* ft^2*/gram*

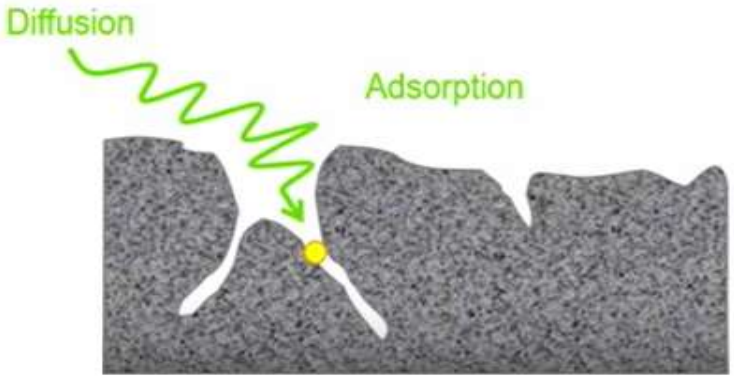
- Molecules diffuse from the external air into the large pores. Molecules then diffuse into the very fine pores, collide with, and become trapped on the internal surface.



MECHANISM OF GAS REMOVAL ON DIFFERENT ADSORBENTS

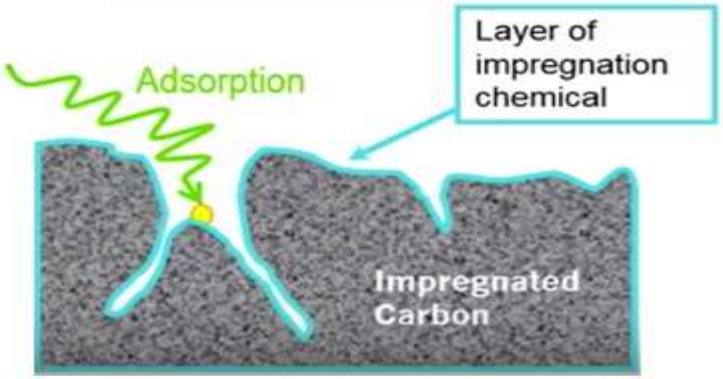
Physisorption

- Low energy binding between a molecule and the surface of the activated carbon or adsorbent



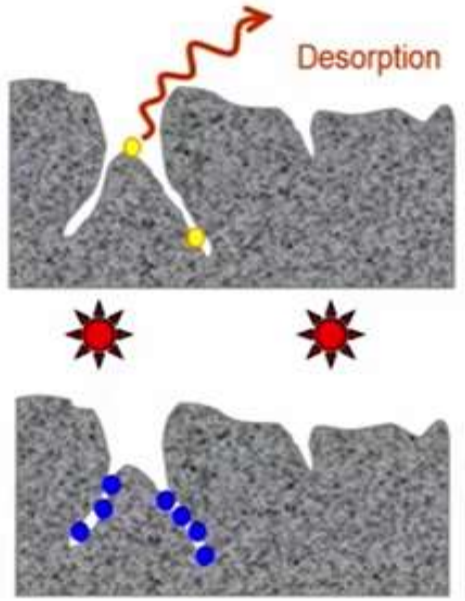
Chemisorption (for gases too volatile to be removed by physisorption)

- Irreversible chemical binding between a molecule and the impregnation of the Impregnated carbon or adsorbent



Factors Affecting Performance

Increasing ↑	Carbon type	Efficiency	Lifetime	Pressure loss
Temperature	Broad spectrum carbon	↓	↓	
	Impregnated carbon	↑	↔	
Relative humidity	Broad spectrum carbon	↓	↓	
	Impregnated carbon	↑	↔	
Particle size	Broad spectrum carbon	↓	↓	↓
	Impregnated carbon	↓	↓	↓
Contact time	Broad spectrum carbon	↑	↑	
	Impregnated carbon	↑	↑	



Common Adsorbents

- Activated Carbon
  - Coconut shell
  - Coal base

    Activated carbon can be virgin or impregnated

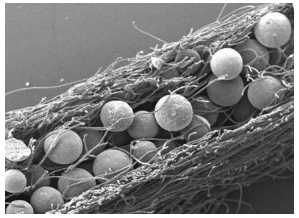
  - Activated Alumina

    Alumina is impregnated

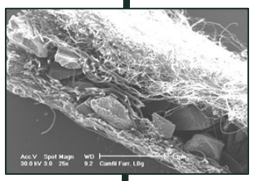
  - Ion Exchange Resin







PRODUCT TYPE AND APPLICATION AREA

Media	Embedded media (RAD)	Loose-fill media Thin bed	Loose-fill media Deep bed
			
Product Form	Compact, Panel, Cell, Bag	Cylinder, Panel, Vee-Cell	Loose-fill media Deep bed
Application Area	IAQ	Traditional Comfort, Light Process	Process, Industrial and Corrosion Control
Primary Air System	Re-circulation / Return	Make-up	Make-up, Exhaust / Re-circulation
			

GLOBALLY RECOGNIZED STANDARDS


MOLECULAR FILTRATION LABORATORY
CLEAN AIR SOLUTIONS
camfil

STANDARDS RELATED TO MOLECULAR FILTRATION PERFORMANCE

- **ISO 10121: 2014**

Test method for assessing the performance of gas-phase air cleaning media and devices for general ventilation, Parts 1 and 2.

  - *Media and full size filter testing, application realistic concentrations, many different challenge gases.*

- **ASHRAE 145: 2015**

Laboratory Test Method for Assessing the Performance of Gas-Phase Air Cleaning Systems: Loose Granular Media, Parts 1 and 2.

  - *Media and full size filter testing, application realistic concentrations, many different challenge gases.*

- **ASTM D6646 (2014)**

Standard Test Method for Determination of the Accelerated Hydrogen Sulfide Breakthrough Capacity of Granular and Pelletized Activated Carbon

  - Media only testing, artificial test conditions (highly accelerated)
  - Not representative of real-world conditions.

ASTM D6646

https://www.astm.org/Standards/D6646.htm

- Excerpt from 5.1: “This method compares the performance of granular or pelletized activated carbons used in odor control applications, such as sewage treatment plants, pump stations, etc. The method determines the relative breakthrough performance of activated carbon for removing hydrogen sulfide from a humidified gas stream. Other organic contaminants present in field operations may affect the H_2S breakthrough capacity of the carbon; these are not addressed by this test.”

- Excerpt from 5.2: “This test does not duplicate conditions that an adsorber would encounter practical service.”

- “The mass transfer zone in the 23 cm column used in this test is proportionally much larger than that in the typical bed used in industrial applications. This difference favors a carbon that functions more rapidly for removal of H_2S over a carbon with slower kinetics.”

FOCUS APPLICATION

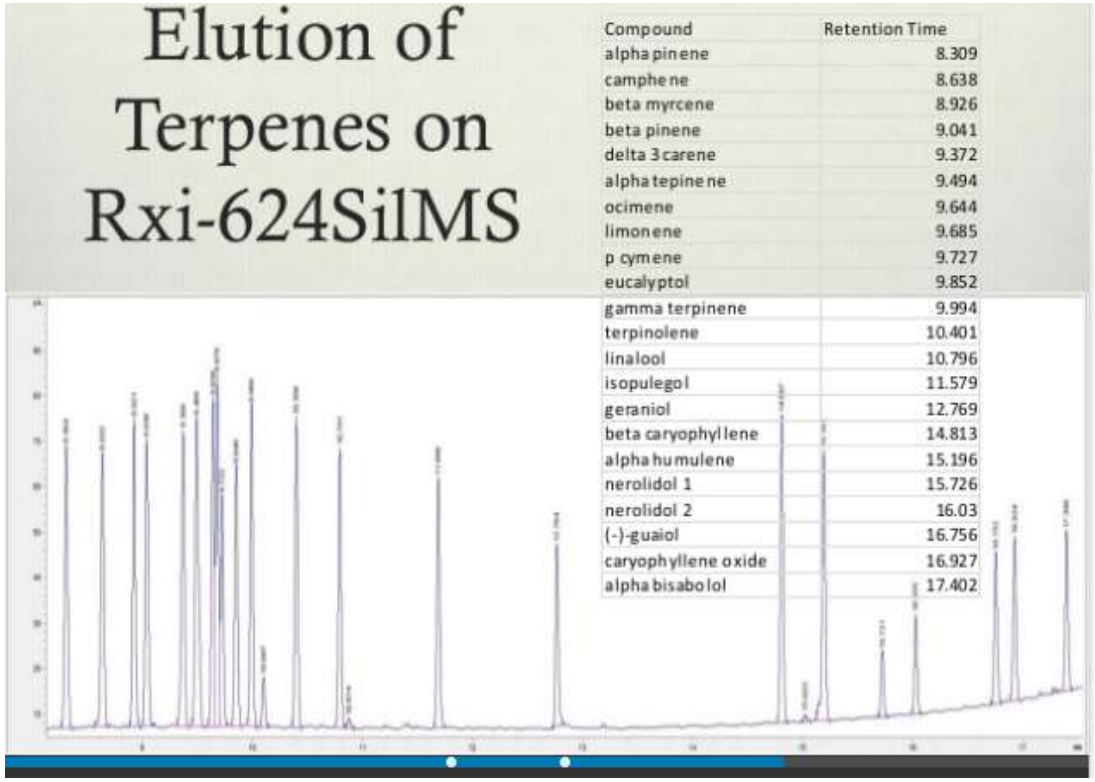
MOLECULAR FILTRATION DESIGN

1. What is the industry?
   - Cannabis Cultivation

2. Why do we need particulate filters?
   - To improve IAQ for consistency of the crops and to maximize the yield
   - To remove particles, microbiological contaminants and Pollens, growth control of Powdery Mildew and Mold

3. Why do we need molecular filtration?
   - Nothing harmful
   - Odour Control- Terpenes: alpha-pinene, beta-pinene, beta myrcene, beta-caryophillene and limonene

4. What products to consider?



Source:
Rebecca Plessel,
Dorman lab, Penn State University

Other VOCs present:
N-heptanal
Toluene
p,m-Xylene
Methyl methacrylate
Ethanol

Source:
TERPENE ODORS ESCAPING FROM CANNABIS GROWING
By Richard L. Knights, Ph.D., Blue Sky Testing Labs, Seattle

	Odor thresholds
β-Myrcene	13 ppb
α-Pinene	18 ppb
Limonene	38 ppb
B-Pinene	33 ppb

Source:
TERPENE ODORS ESCAPING FROM CANNABIS GROWING
By Richard L. Knights, Ph.D., Blue Sky Testing Labs, Seattle

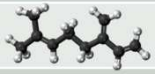
TEST PARAMETERS

Temperature	70 °F (23 °C)
Relative humidity	50 %
Residence time	0.1 s

Molecular Performance Testing: Specification Verbiage

Molecular Performance Testing

- Filters to be tested by the manufacturer using a protocol in accordance with ASHRAE 145.2 or ISO 10121-2. Full details of test protocol to be included with photographic evidence. Results from ASTM D6646 or similar high challenge concentration tests are not admissible
- A full size, 24” x 24” filter, shall be tested at a flow rate of 2,000 CFM, temperature of 73F (23C), and a relative humidity of 50%.
- Gas detectors must have lower level of detection (LLoD) values <1 ppb.
- At a minimum the initial removal efficiency and test concentration shall be provided for:
  - Beta myrcene
  - Alpha pinene
  - Ozone (if recirc)
  - Nitrogen dioxide (if recirc)

Parameter	Chemical properties
Substance	Beta-myrcene
Molecule	
Mol.Formula	$C_{10}H_{16}$
Cas No	123-35-3
Mol weight [g/mol]	136.24
Boiling point [^{o}C]	166-168
Vapor pressure @ 23^{o}C [kPa]	0.251
Refractive index	1.471
Density [g/cm^{3}]	0.794
Saturated air @ 23^{o}C [ppm]	2477
Odor threshhold [ppb]	13

Sources:
Prevent – Chemical substances database
NIST – Chemistry webbook

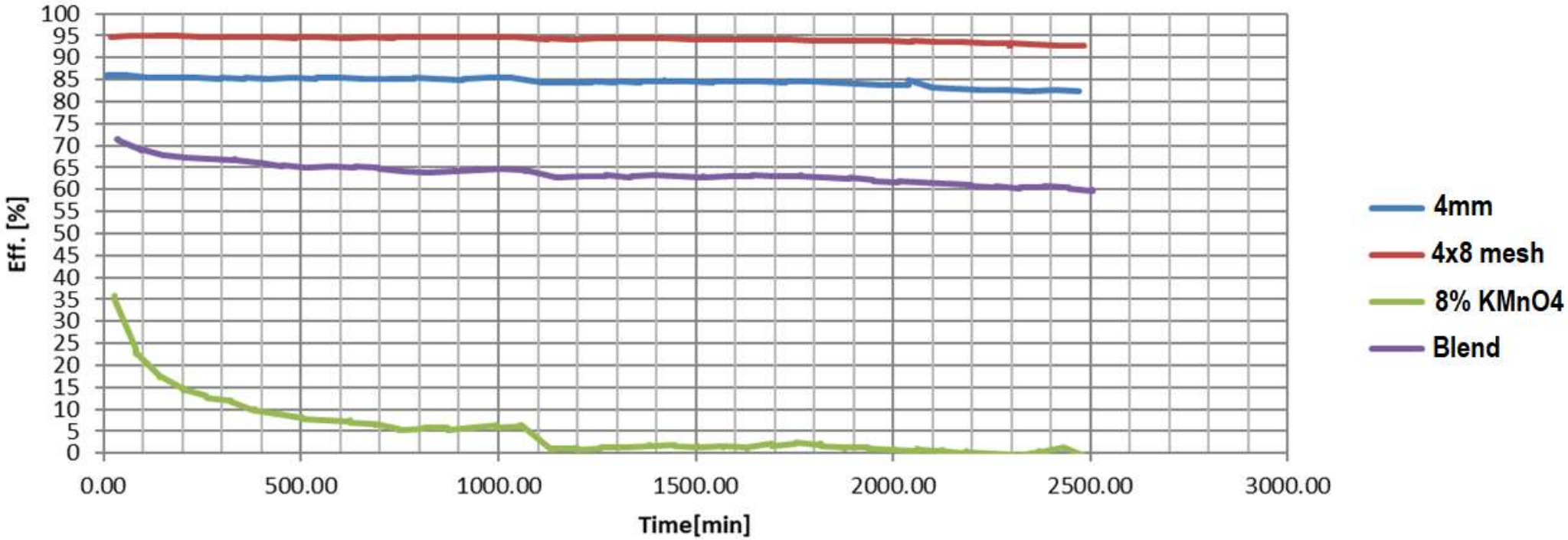
Myrcene, or β-myrcene, is an olefinic natural organic hydrocarbon. It is more precisely classified as a monoterpene. Monoterpenes are dimers of isoprenoid precursors, and myrcene is a significant component of the essential oil of several plants, including bay, **cannabis**, ylang-ylang, wild thyme, parsley, cardamom, and hops. It is produced mainly semi-synthetically from myrcia, from which it gets its name. It is a key intermediate in the production of several fragrances. [Wikipedia]

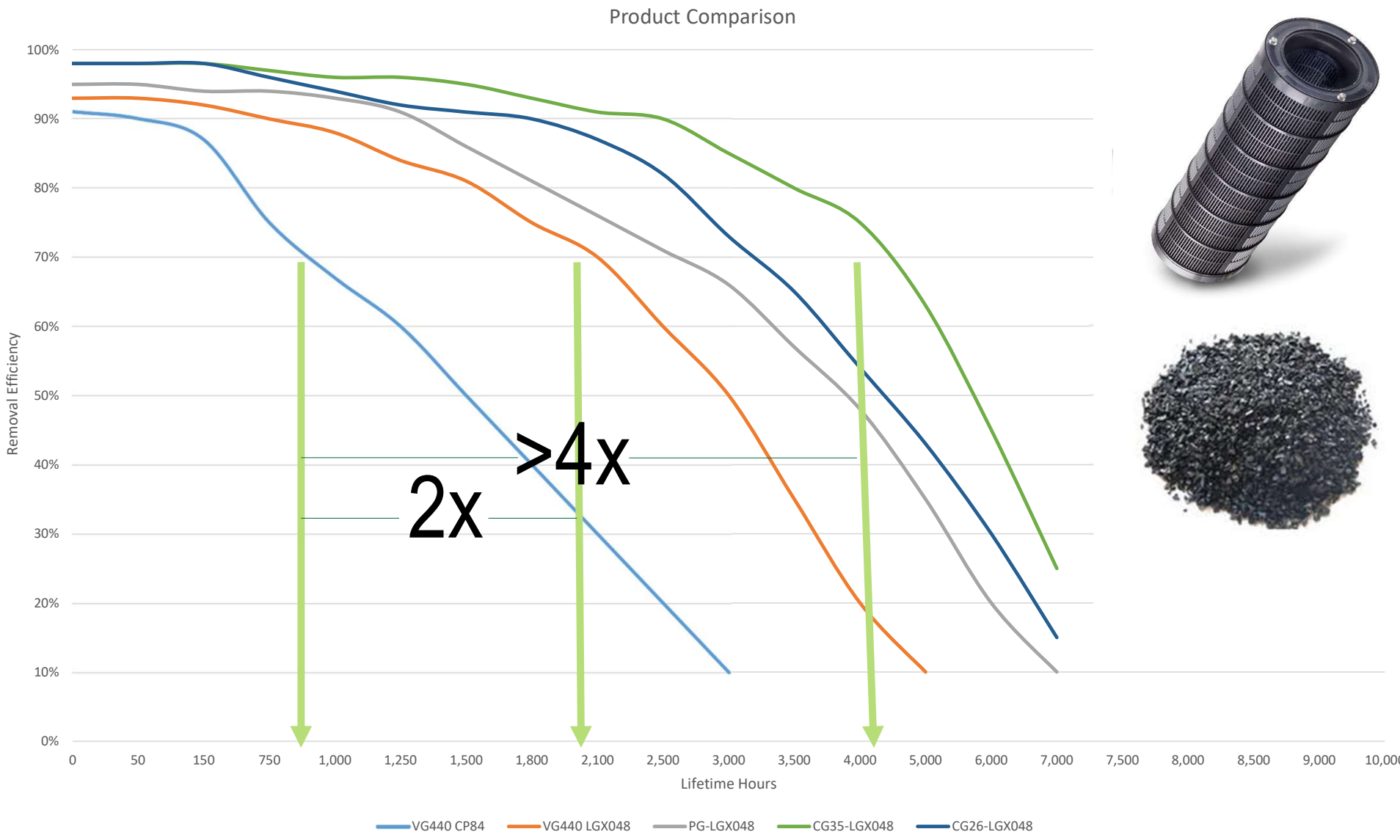
Beta-Myrcene is probably the best marker for Cannabis odor, being one of the most abundant around cannabis grow rooms/cultivation.

	4x8 Mesh Activated Carbon	4mm Activated Carbon	8% Potassium Permanganate	Blend
Base material	Coconut shell	Coal	Alumina oxide + $KMnO_4$	
CTC [%]***	62	68	2	
Micro pore volume [cm3/g]*	0.39	0.42	0.014	
Micro pore volume [cm3/g]**	0.38	-	-	
Particle size [us.mesh]	4x8	-	-	
Particle size [mm]	-	4	3-5	

• Calculated from adsorption at Toluene saturated air
** Calculated from adsorption Beta-Myrcene saturated air
** Mesured with Toluene and recalculted into CTC

Efficiency vs Time

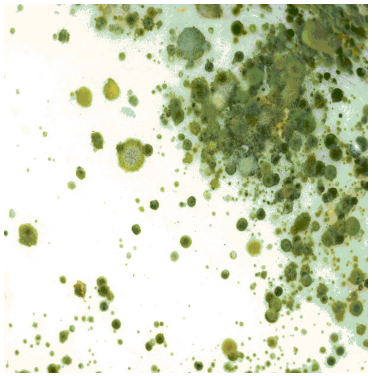


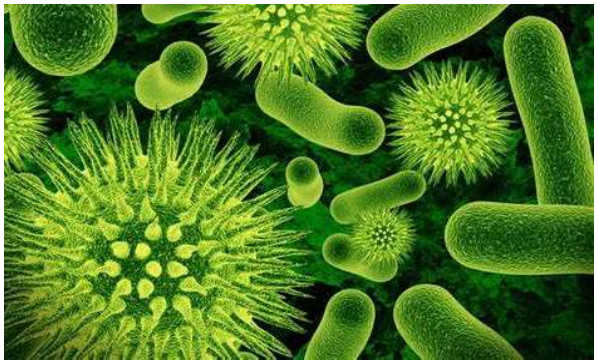

Product Comparison
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Removal Efficiency
0
50
150
750
1,000
1,250
1,500
1,800
2,100
2,500
3,000
3,500
4,000
5,000
6,000
7,000
7,500
8,000
8,500
9,000
10,000
Lifetime Hours
2x
>4x
VG440 CP84
VG440 LGX048
PG-LGX048
CG35-LGX048
CG26-LGX048

HOW AIR FILTRATION BENEFITS CANNABIS CULTIVATION

- Selecting the right air filter reduces total cost of ownership

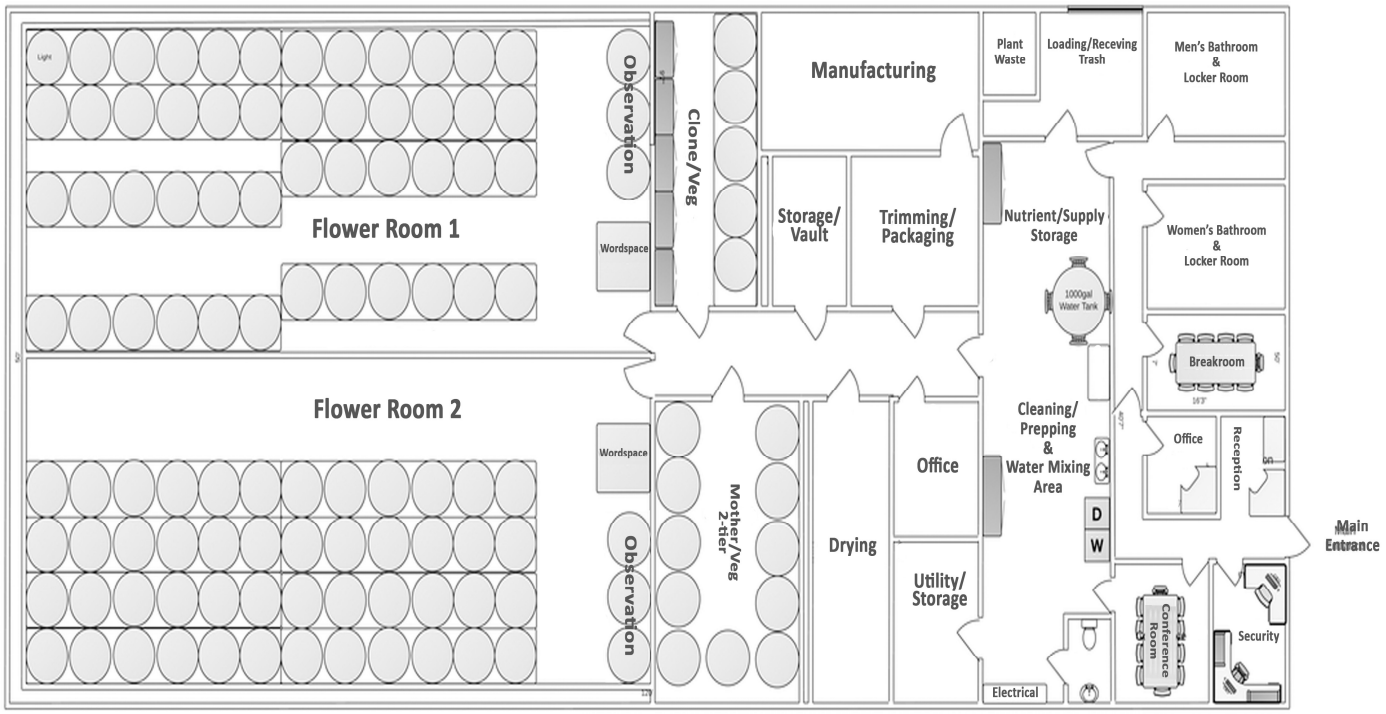
- Air filters have the main role in maintaining the environment clean and healthy.





LAYOUT OF CANNABIS CULTIVATION FACILITY

- Flower Room (Cultivation room)
- Mother Room
- Vegetative Room
- Trimming Room
- Drying Room
- Storage Room
- Packaging
- Shipping
- Offices
- R&D



CANNABIS CULTIVATION-AIR FILTER REQUIREMENT BY ROOM

- Odour Control
  Molecular filtration in Exhaust air and Return air

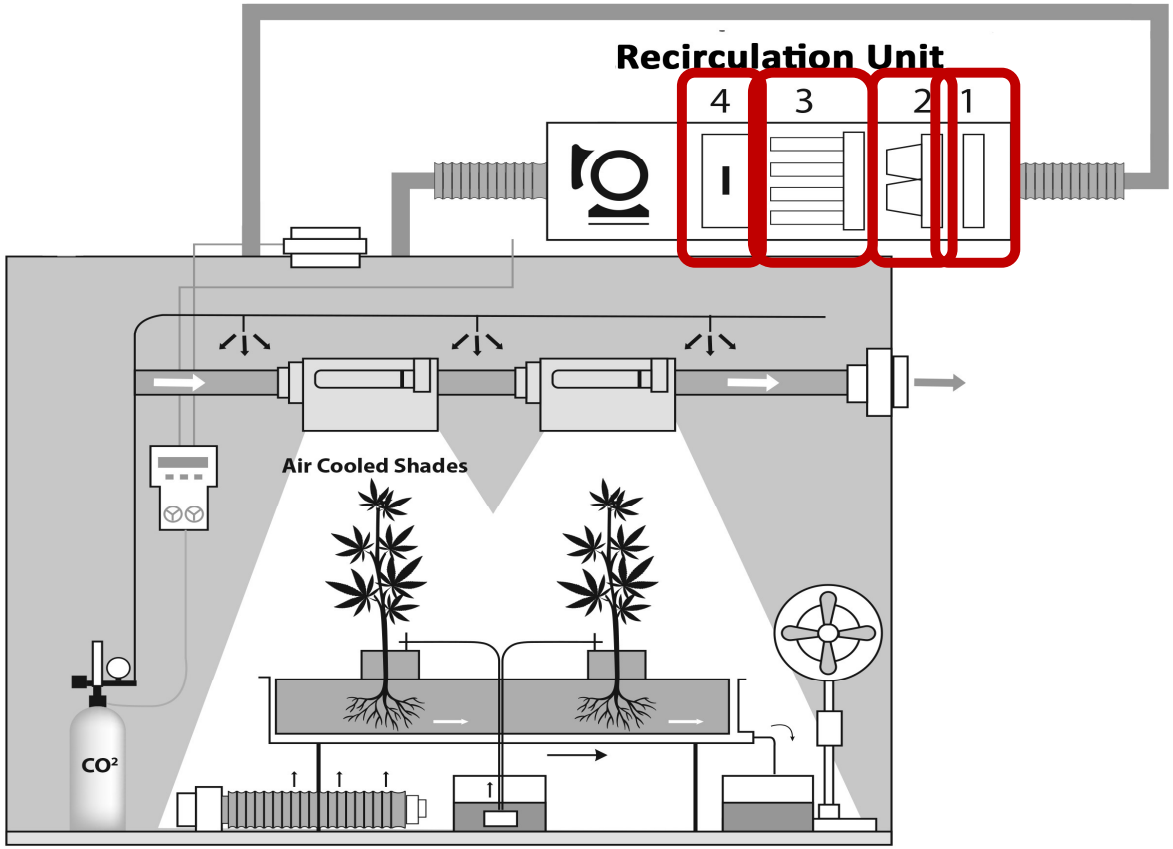
- Indoor Air Quality improvement
  Particulate filtration in Make up air and Return air

Room	Make up air	Exhaust	Recirculate	ACH
Flowering Rooms	HEPA/ Molecular	MERV. 13 - Molecular	MERV. 13 - Molecular	8-10
Mother Rooms	HEPA/ Molecular	MERV. 13 - Molecular	MERV. 13 - Molecular	8-10
Trimming	HEPA	MERV. 13 - Molecular	MERV. 13 - Molecular	12-16
Drying	HEPA	MERV. 13 - Molecular	MERV. 13 - Molecular	12-16
Veg. Rooms	HEPA/ Molecular	MERV. 13 - Molecular	MERV. 13 - Molecular	8-12
Storage Room	HEPA	MERV. 13 - Molecular	MERV. 13 - Molecular	10-12
Packaging	HEPA	MERV. 13 - Molecular	MERV. 13 - Molecular	10-12
Shipping	MERV 13	MERV. 13 - Molecular	MERV. 13 - Molecular	8-12
Offices	MERV 13 / Molecular		MERV. 13 - Molecular	6-8
R&D laboratory	as per cleanroom classification requirement			

FLOWERING ROOM, TRIMMING ROOM, DRYING ROOM

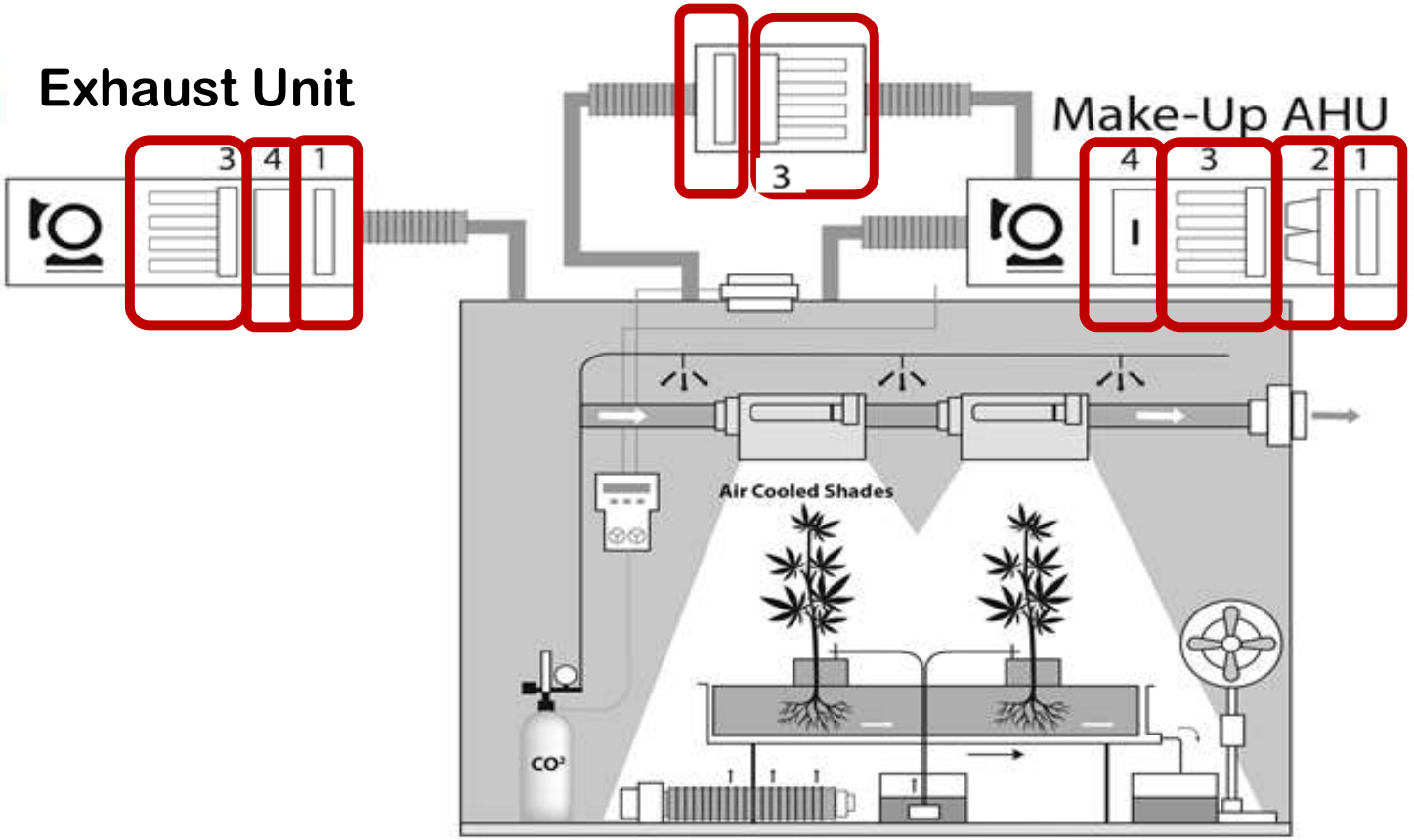
Not only odour mitigation is required , but also particulate filtration is very important too.

MECHANICAL LAYOUT OF FLOWERING, MOTHER & VEG. ROOMS



MERV 9A Pre-Filter
MERV 13A Filter
Carbon Filled Cylinders
HEPA 99.97% Filter

MECHANICAL LAYOUT OF A DRYING, TRIMMING ROOM



MERV 9A Pre-Filter
MERV 13A Filter
Carbon Filled Cylinders
HEPA 99.97% Filter

Summary

- Molecules can impact humans in many ways, most importantly by impairing health.
- Molecular filtration is very different to particulate filtration.
- We have many molecular filtration solutions to suit specific applications.
- In Cannabis cultivation, we need particulate filtration for consistency of the crops and to maximize the yield.
- The main concern in Cannabis cultivation is odour control. Nothing Harmful.
- ASTM D6646 Not representative of real-world conditions. ASHRAE 145 and ISO 10121 are better aligned to realistic concentrations.
- Coconut shell activated carbon shows the highest performance in odour control associated with Cannabis application

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