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AURA AIR

AURA AIR
White Paper

Aura

ABOUT AURA AIR

At Aura Air, we believe the act of breathing should be as nature intended. *Clean, pure and simple.*
A constant since birth, breathing sets our life's rhythm. Inhale. Exhale. Fresh clean air clears our mind and rejuvenates our body without us committing a second thought.

With a quest to reclaim our natural right to clean air, Aura Air developed the world's smartest air purification system, one that cleanses and disinfects your indoor air while vigilantly monitoring its quality in real-time. Cutting-edge in design, Aura is remarkably simple to install and effortless to operate. Just hang it up and plug it in. We"ll do the rest.

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Because breathing shouldn't require a second thought.

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Introduction

Why is indoor air quality so important?

People in today's world spend most of their time indoors: in their homes, offices, schools, in malls, and in many other public and private places. The indoor air can be up to 5 times more polluted than outdoor air according to the US EPA [1], yet it is not regulated in most of the world. That means that for many people, the health risks of exposure to indoor air pollution may be greater than exposure to outdoor air pollution. Understanding the source of pollution and its composition is a key element for improving the indoor air quality. After analyzing the sources of pollution, taking action is necessary for treating it. In this paper, we intend to review the key indoor pollutants and their health effects and present our Aura Air solution for battling pollution and improving indoor air quality.

"Indoor air can be up to 5 times more polluted than outdoor air"

Key Parameters and their Health Effect

CO2

Carbon dioxide is a colorless gas that is naturally present in the earth's atmosphere. It is produced by all the organisms on earth that perform respiration. It is an essential gas for life on earth since plants use it for photosynthesis [2]. However, in high concentration that can often occur in indoor environments, it can have harmful effects that may include headaches, dizziness, restlessness, tingling or pins-and-needles feeling, difficulty breathing, sweating, tiredness, and increased heart rate [3]. That's why it is important to monitor its levels in indoor environments.

CO

Carbon monoxide is a colorless, odorless and toxic gas that is produced in a combustion process such as fuel burning in cars, cooking, using fireplaces and more. It can accumulate indoors and poison people and animals who breathe it [5]. The most common symptoms of CO poisoning are headache, dizziness, weakness, upset stomach, vomiting, chest pain, and confusion. CO symptoms are often described as "flu-like." If a person breathes in a lot of CO it can lead to fainting and even death [5].

VOCs

Volatile organic compounds are compounds that easily become vapors or gases. They are released from burning fuel such as gasoline, wood, coal or natural gas. They are also released from many consumer products such as cigarettes, solvents, paints, glues, wood preservatives, cleaners, disinfectants, air fresheners, building materials, pesticides and more. Formaldehyde, ethanol, toluene, and benzene are just a few examples of VOCs. Not all VOCs are harmful, but a large number of them are [4]. Some of the health effects of VOCs are short-term such as irritation of the eyes, headaches, and dizziness. Others have long term effects such as fatigue, loss of coordination, liver and kidney damage and even cancer [4].

PM2.5 and PM10

Particulate matter (PM) or also known as atmospheric aerosol particles are microscopic solid or liquid matter suspended in the atmosphere of Earth. These particles include coarse particles with a diameter of 10 µm or less (PM10) and fine particles with a diameter of 2.5 µm or less (PM2.5). PM10 includes particles as dust, pollen, and mold. PM2.5 includes particles such as combustion particles, organic compounds, metals, bacteria and more [6]. The effects of inhaling particulate matter that has been widely studied in humans and animals include asthma, lung cancer, respiratory diseases, cardiovascular disease, premature delivery, birth defects, low birth weight and premature death [7].

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Pollen

Pollen is one of the most common triggers of seasonal allergies. Each spring, summer and fall, plants release minuscule pollen grains to fertilize other plants of the same species. Most of the pollens that cause allergic reactions come from trees, weeds, and grasses. These plants make small, light and dry pollen grains that travel by wind [8]. People with pollen allergies only display symptoms when the pollens they are allergic to are in the air. The symptoms include a runny nose, mucus production, sneezing, itchy nose, eyes, ears and mouth, swelling around the eyes and more [8].

AQI

An air quality index (AQI) is used by government agencies to communicate to the public how polluted the air currently is or how polluted it is forecast to become. Different countries have their own air quality index, corresponding to different national air quality standards. An example of an AQI is presented in Fig X. Computation of the AQI requires an air pollutant concentration over a specified averaging period, obtained from an air monitor or model. Taken together, concentration and time represent the dose of the air pollutant [9]. The values of the AQI are typically grouped into ranges. Each range is assigned a color code. Most of the AQI's are assigned for outdoor air quality. Aura created its own AQI for indoor air quality that relies on innovative research and occupational standards. Our AQI scale is similar to

Figure 1: USA air quality index [12]

Index Values	Levels of Health Concern	Cautionary Statements
0-50	Good	None
51-100*	Moderate	Unusually sensitive people should consider reducing prolonged or heavy exertion outdoors.
101-150	Unhealthy for Sensitive Groups	Active children and adults, and people with lung disease, such as asthma, should reduce prolonged or heavy exertion outdoors.
151-200	Unhealthy	Active children and adults, and people with lung disease, such as asthma, should avoid prolonged or heavy exertion outdoors. Everyone else, especially children, should reduce prolonged or heavy exertion outdoors.
201-300	Very Unhealthy	Active children and adults, and people with lung disease, such as asthma, should avoid all outdoor exertion. Everyone else, especially children, should avoid prolonged or heavy exertion outdoors.
301-500	Hazardous	Everyone should avoid all physical activity outdoors.

Indoor Air Quality Standards

The previous section examined the different air pollutants and their health impacts. It is quite clear that some standards for indoor air quality should be determined. In this section, we will review the emerging standards that are being developed in the world.

OSH

Occupational safety and health is a field that ensures the safety and health of the people at work [13]. Each country has its own set of standards and regulatory authority to enforce them. The first standards for indoor air quality and air testing started from this field, especially in industries like coal mining, gas, and petrochemical processing in which people are exposed to chemicals during their workday but it is also evolving to more modern work environments like offices and open spaces.

LEED

Leadership in Energy and Environmental Design (LEED) is one of the most popular green building rating systems in the world. Green building is the practice of designing, constructing and operating buildings to maximize occupant health and productivity, use fewer resources, reduce waste and negative environmental impacts, and decrease life cycle costs [14]. When it comes to indoor air quality, LEED defines standards of certain pollutants that has to be monitored prior to the occupancy of a new building or after renovation of an old one. These pollutants include PM2.5, PM10, CO, ozone, tVOC, Formaldehyde and specific VOCs like Benzene and Toluene [15]. The disadvantage of LEED standards is that it doesn’t monitor those pollutants after occupancy.

RESET

RESET is the first sensor-based building standard and certification program for air quality monitoring. It defines the parameters that has to be monitored online, their values, the types of monitors that should be used, the way to save the data and the way to communicate the results to the public [16]. The monitored parameters in this standard are CO2, tVOC, PM2.5, temperature and humidity.

Methods

Types of Air Quality Sensors

There are several types of air quality sensors available in the market.

This paper will review the most prevalent types.

Electrochemical sensors

Electrochemical sensors are the most common ones. They operate by reacting with the chemical solutions and producing an electrical signal that is proportional to the analyte concentration [10]. These are mostly gas detectors like carbon monoxide.

NDIR sensors

NDIR sensors stands for nondispersive infrared sensors. This is a simple spectroscopic device that works in the IR spectrum and identifies gases by their typical light absorption [11]. These typical gas detectors include carbon dioxide and methane.

MOX sensors

Metal oxide sensors (MOX) are a type of semiconductor sensors. They detect gases by a chemical reaction that takes place when the gas encounters the resistor (which is the metal oxide). The change in the resistance is proportional to the gas concentration [12]. Common gas sensors of this type are VOCs sensors, hydrogen sensors and ozone sensors. Hydrogen sensors are also used to determine the amounts of CO_2 emitted from breathing of humans, that exhale hydrogen together with CO_2 [13]. That parameter is called equivalent CO_2 (eCO_2).

Light scattering sensors

Light scattering is a physical process when incident light of energy is absorbed by a system and subsequently another light of energy is emitted [14]. Light scattering sensors are used for measuring particulate matter (also called dust sensors). The energy emitted from the particle is proportional to its size and volume.

Laser particle sensors

Laser particle sensors use laser beams to detect particles going past by their reflectivity. The reflection of the light is proportional to the size of the particles [15].

Traditional Methods for Air Testing

Formaldehyde testing – the sampling method is NIOSH 2016 [16]- according to this method, formaldehyde must be tested on special silica cartridges connected to an air pump. The air is pumped to the cartridge and the formaldehyde is absorb into the silica. Then the cartridge is taken to a lab for elution of the formaldehyde with acetonitrile and analysis using high pressure liquid chromatography (HPLC) with a UV detector. The principle of the method is to separate and identify different substances by their chemical properties and their unique absorbance in UV [17].

tVOC testing- the sampling method is NIOSH 1400 [18] – according to this method, the VOCs must be tested on carbon tubes connected to an air pump. The air is pumped to the cartridge and the VOCs are absorb to the carbon. Then the tubes are taken to a lab for desorption of the VOCs and analysis using gas chromatography- flame ionization detector (GC-FID). The principle of the method is to separate and identify different gases by their chemical properties and by the number of ions of each gas [19] (that is proportional to the concentration of the gas).

Particulate matter testing- the sampling method is NOISH 0500 [20]. The method is based on the principle of gravimetric settling – air is being pumped through a filter with a known weight and the particles settle on it. Then the filter is weighted again, and the mass of the particles is calculated.

Air Treatment Technologies in Aura Air

HEPA filter

HEPA stands for high-efficiency particulate air and it is an efficiency standard for air filters [21]. The efficiency is measured in the ability of the filter to retain particles larger than 0.3 µm. These filters are used in environments that require a contamination control as food and pharmaceutical industries, hospitals, semiconductors and in vehicles and homes [21].

The structure of those filters consists of randomly arranged fibers, typically from fiberglass [22]. The diameter of the fiber ranges between 0.5-2 µm [22]. The efficiency of the filter is determined by the fiber diameter, filter thickness and the face velocity (which is the air speed in the inlet of the filter) [22]. These filters have several classes which are distinguished by the removal efficiency of the particles. The classes of the filters are shown in Table 1:

Table 1- Classification of HEPA filters [23]

HEPA class	Retention efficiency (%)
E10	≥85%
E11	≥95%
E12	≥99.5
H13	≥99.95
H14	≥99.995
U15	≥99.9995
U16	≥99.99995
U17	≥99.999995

Carbon Filter

Carbon filtering is a method that uses a bed of activated carbon to remove contaminants using a process called adsorption [24]. In this process, the molecules of the pollutant are trapped inside the porous structure of the carbon. This is a very effective method in the treatment of water and air, and it effectively removes volatile organic compounds (VOCs) and bad odors from air and water [24]. The efficiency of the carbon filter is determined by the amount of carbon inside the filter and the flow rate- the slower the rate of the air through the filter, the higher the exposure time of pollutants, the higher the efficiency of removal is as well [25].

Smart Fabric

Our smart fabric is made from cotton impregnated with copper oxide. Copper is a powerful anti-bacterial agent that also has the ability to neutralize viruses, fungus, and mold [26]. This is a patented and EPA-approved technology. The smart fabric is integrated into our Ray filter™ to enhance the ability of the filter to successfully deal with these pollutants. Fig. 1 shows a microscopic image of our smart fabric [27].

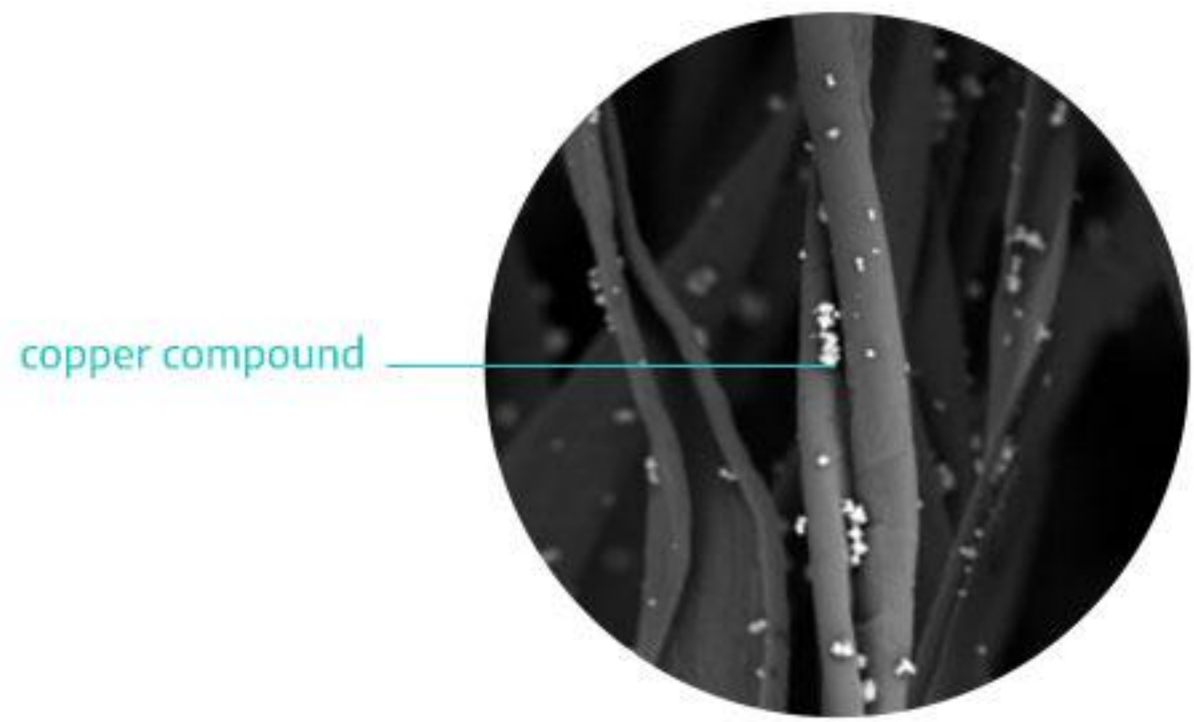

Figure 1: A microscopic image of the copper saturated fabric

Sterionizer

The Sterionizer is a device based on the technology of bipolar ionization. The process of ionization uses UV light and electric currents to transform molecules of oxygen (O_2) into two atoms (O) [28]. In this process, one of the atoms has an electron attached to it and as a result, it has a negative charge (O-) because electrons are negatively charged, and the other atom lacks an electron and is positively charged (O+) [28]. These atoms are very chemically active and when they attack molecules of water that are present in the air- there are two types of molecules formed: OH- and H_2O_2. These molecules attack and neutralize different pollutants- bacteria, fungus, mold, and viruses [29]. This technology has another advantage- unlike unipolar ionization that produces high amounts of ozone (O3)- which is a dangerous substance, the Sterionizer emits very low concentrations of ozone that cause no health damage.

Pre-filter

The pre-filter is a filter that removes large unwanted contaminants from air and water. In HVAC systems and air purifiers, it is usually a washable mesh made from polymers like polypropylene [30]. The pre-filter catches large particles of dust, pollen, insects, animal hair and other large particles [30]. The pre-filter has also a role in the extension of the life of the more sensitive filters that come after the pre-filter such as the HEPA filter.

UVc LEDs

Ultraviolet pressure lamps have been used for decades for the disinfection of air in hoods and clean rooms and for water disinfection. They are effective in neutralizing bacteria, viruses, and parasites by hurting the proteins on the cell membrane [31]. In the past several years UVc-LEDs showed the potential to replace those traditional lamps. These UVc-LEDs that work in the range of 267-310 nm were tested for water disinfection and the wavelength of 275 nm was found to be the most efficient and suitable replacement for the traditional lamps [32]. Although there isn't enough research done on these lamps in air, they have a promising potential to have a meaningful effect in air as well and for this reason they will be tested for Aura's device.

Experimental Setup for Sensor Testing

Aura's tests for evaluating the air quality sensors were made both in a chamber and in an open space of an office. The chamber included air circulation and inlet for gases. Parameters like CO2 and PM2.5 were compared to calibrated devices. tVOC measurement in general and Formaldehyde specifically were compared to the traditional methods described in section 2.2.1 and 2.2.2 respectively. Formaldehyde and ethanol were generated using an aqueous solution and was evaporated inside the chamber using a hot tray. The experimental setup is presented in Fig. 2. The particulate matter was generated using distilled water and a nebulizer by Philips.

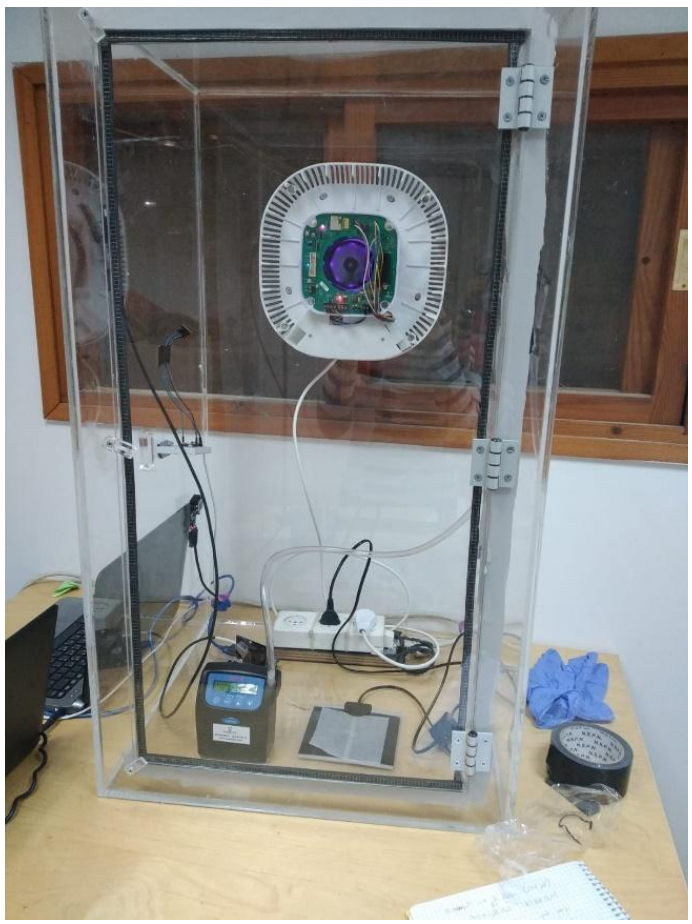

Figure 2: Experimental setup of sensor testing

Experimental Setup for antibacterial efficacy

Aura's tests for evaluating the antibacterial efficacy of the different treatment components was done in a chamber located in an office environment. We used TSA (tryptic soy agar) plates for the growth of bacteria, yeast and mold. The control plates were placed in the chamber throughout the whole experiment (4-5 hours each experimental day). The components tested were the HEPA filter alone, the Ray filter™, the Sterionizer, the UVC LEDs and the whole system. Each time the system was operated for 1-5 min and after that, there was a waiting time of 1 h to enable the micro-organisms to settle on the plates. At the end of each working day, the plates were incubated for 3 days in 22 °C in an incubator for the growth of yeast and mold. After 3 days the plates were counted and transferred to a 32 °C incubator for the bacteria growth of another 5 days of incubation. At the end of the period, the plates were counted one more time. The experimental setup is shown in Figure 3.

Figure 3: Experimental setup for antibacterial testing

Results

Sensors Testing Results

The results of the carbon dioxide gas test are presented in Fig.4.

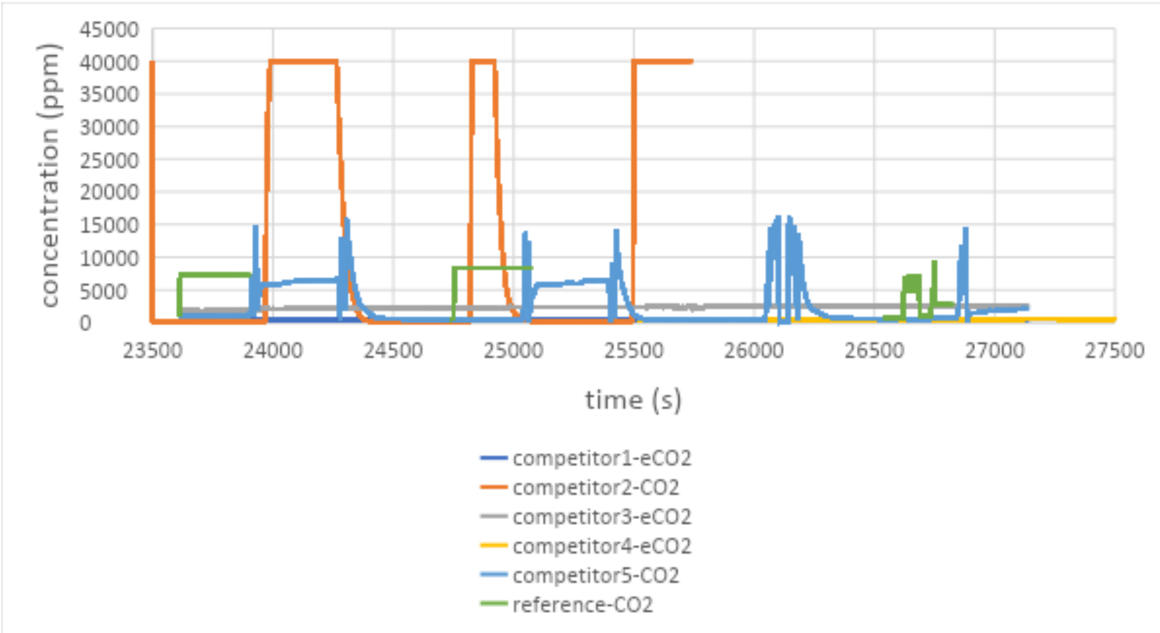

Figure 4–CO_2 gas flow test results

Fig 4 shows that competitor 5 (NDIR sensor) appears to be the best sensor for the measurement of CO_2 when compared to the reference. All the sensors measuring eCO_2 (competitors 1,3,4) didn't respond to the gas flow (since they respond to H_2 and evaluate consequently the concentration of CO_2). Competitor 2 (also an NDIR sensor) is too sensitive and saturates too fast.

The results for testing Furaldehyde in a chamber are presented in Fig. 5.

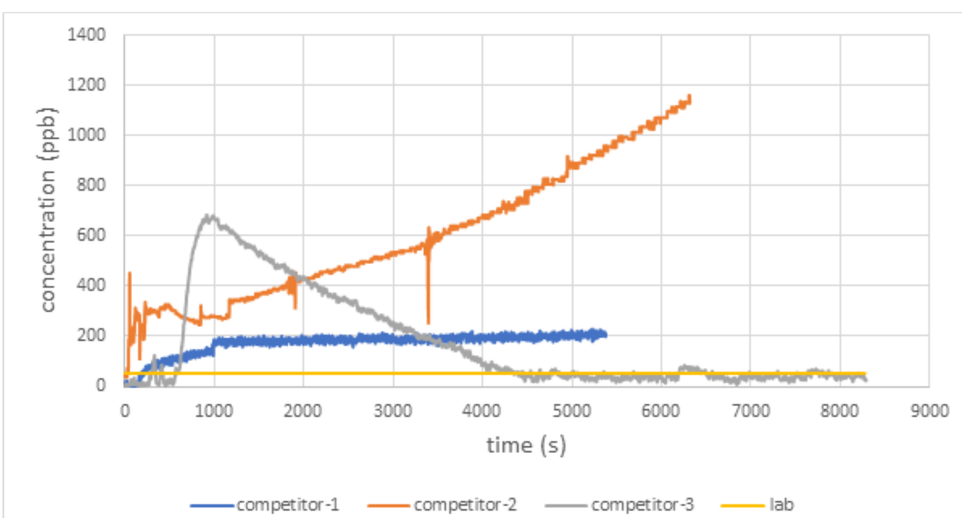

Figure 5- tVOC sensors testing for Formaldehyde

Fig 5 shows that competitor 5 (NDIR sensor) appears to be the best sensor for the measurement of CO_2 when compared to the reference. All the sensors that measured eCO_2 (competitors 1,3,4) didn't respond to the gas flow (since they respond to H_2 and evaluate consequently the concentration of CO_2). Competitor 2 (also an NDIR sensor) is too sensitive and saturates too fast.

The results for testing Furaldehyde in a chamber are presented in Fig. 6.

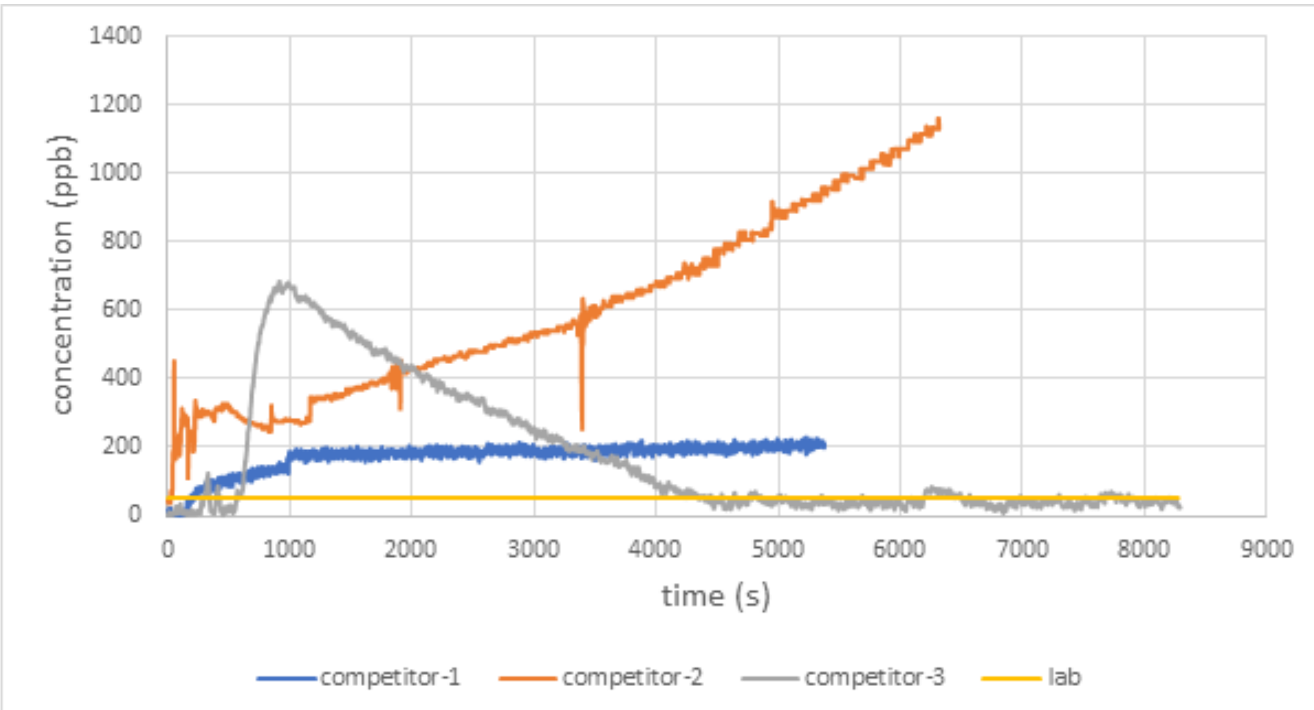

Figure 6- tVOC sensors testing for Formaldehyde

Competitor 1 and 3 showed both similar results in terms of average concentrations, but competitor 1 showed a more accurate pattern with fluctuations in the concentrations of the tVOC when Formaldehyde was added to the chamber. Competitor 2 also had fluctuations in the concentrations, but the concentrations were too high. Competitor 1 was the most accurate sensor when compared to the lab results. All the tested sensors were MOX sensors.

We also did a test in an open space office environment and tested the total VOC emissions in the office. The results are presented in Fig 7.

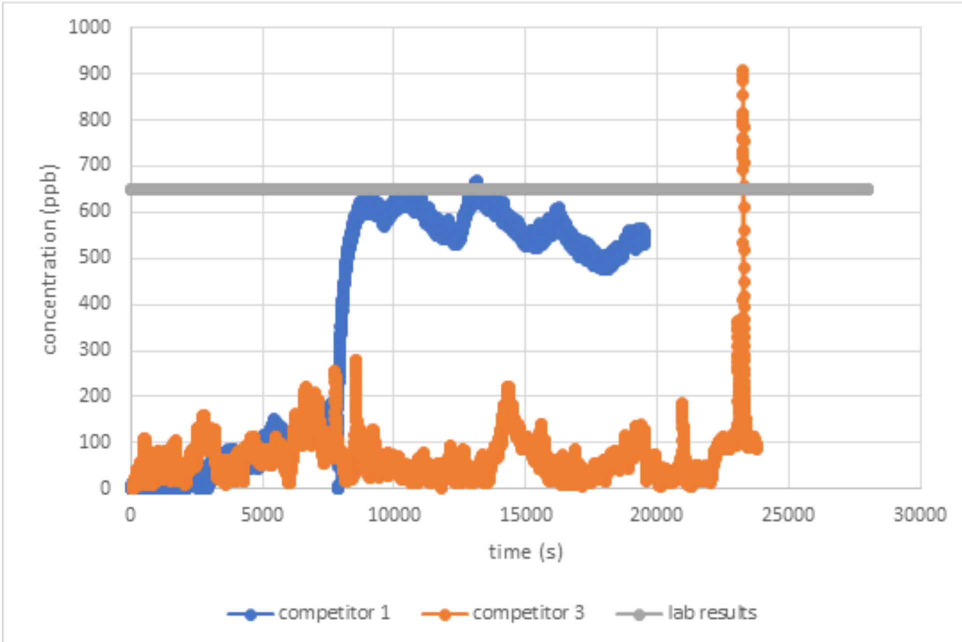

Figure 7- concentrations of tVOC in an office environment

Competitor 1 seems to have the most reliable results compared to the lab results. The results of competitor 2 are too low compared to the lab tests and to competitor 1.

The results for dust sensor testing are presented in Fig 8. The particles created in this test are aerosols of water.

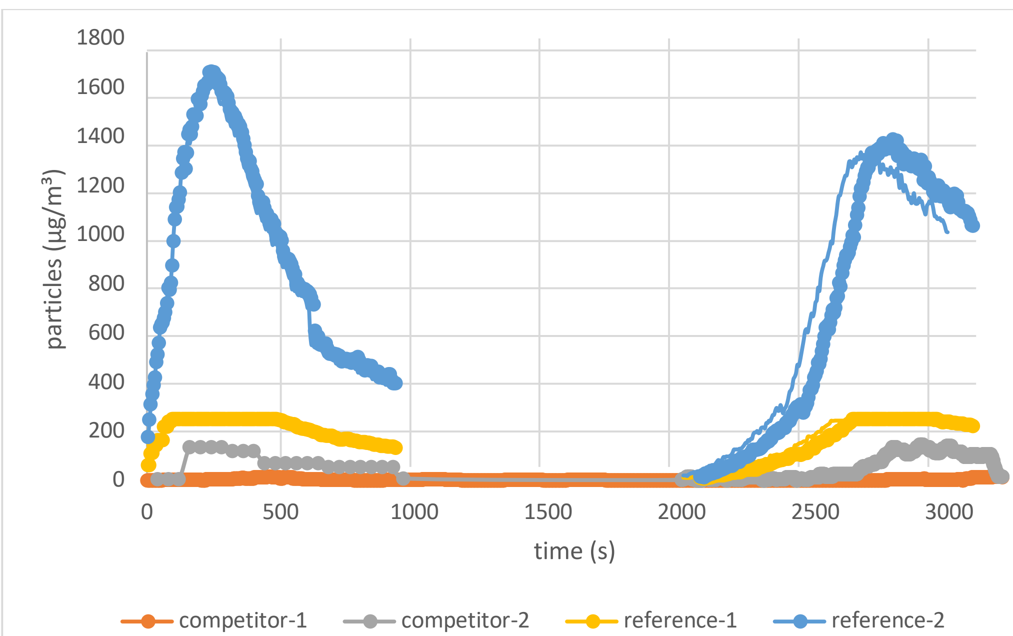

Figure 8- PM2.5 results of aerosols created by a nebulizer

As shown in Fig 8- competitor 1 didn't respond to the particles. Competitor 2 did respond to the particles and had a similar reaction as the reference device no 1. Competitor 2 seems to be a suitable one for PM2.5 measurement in the AURA system. The reference 2 device seems to be more sensitive to particles than reference 1 device. All the tested sensors were from a light scattering kind.

Smart Fabric Results

The efficacy of our smart fabric to decrease bacteria, viruses and mold is presented in Fig 9.

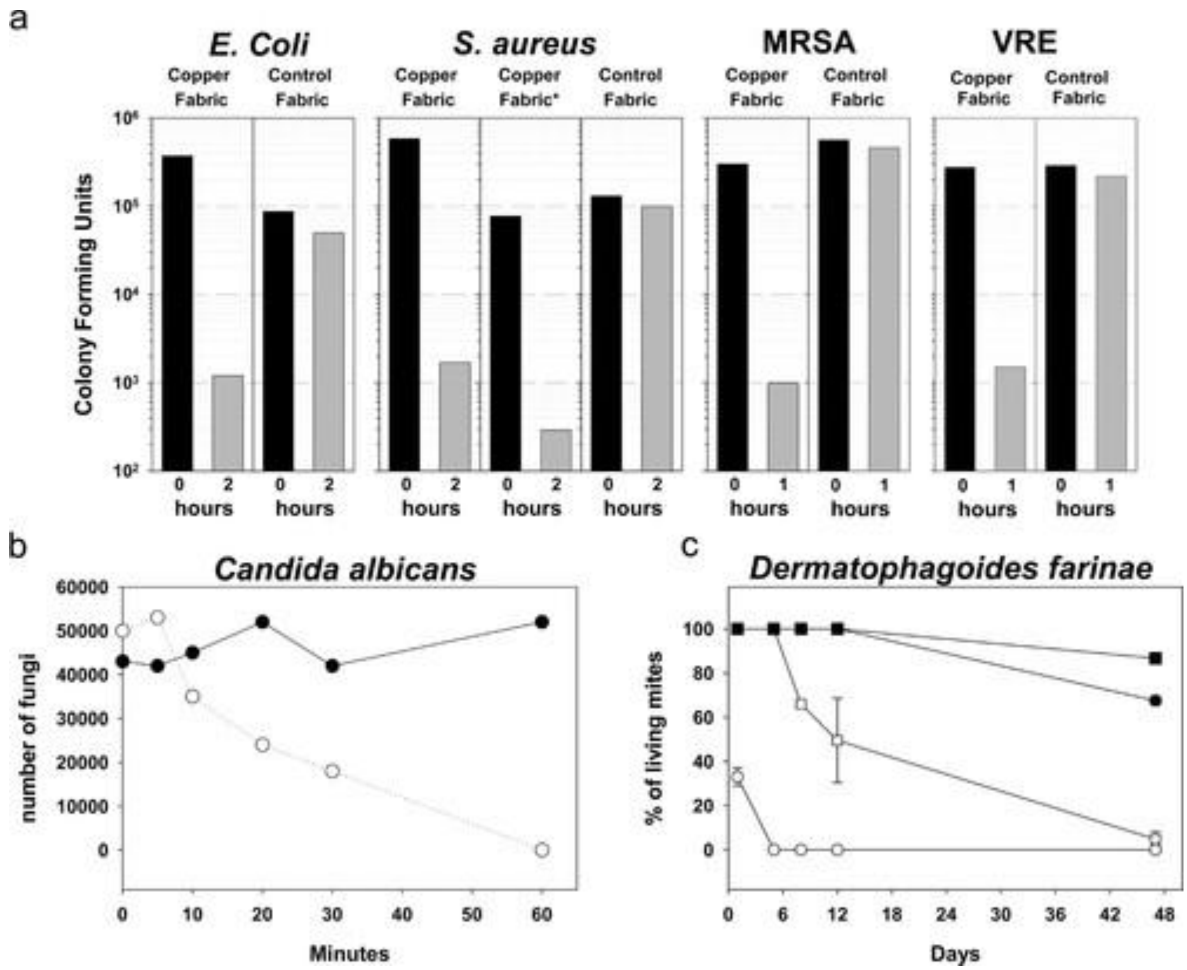

Figure 9. Anti-bacterial, anti-fungal, and acaricidal activity of copper fabrics. a) 1 ± 0.1 mL of a 24 h broth/bacteria culture were exposed to swatches of 20% copper fabrics or control fabrics for ~1 min (0 h) and 2 h (E. coli and S. aureus). Methicillin-resistant stapyhloccus aureaus (MRSA) and vancomycin-resistant enterococci (VRE) were exposed for ~1 min and 1 h. b) 1 ± 0.1 mL of a 24 h broth containing C. albicans were exposed between 0 to 60 min to swatches of control fabric (•) or 20% copper fabric (○). c) Approximately 200 dust mites (D. farinae) were cultured for 48 days in the presence of swatches of control fabric (•), 20% copper fabric (□), 100% copper fibers (○) or in the absence of any swatches (■). [40]

Figure 9-(a) shows that the copper fabric decreased the amount of all kinds of bacteria for more than two logs of reduction (>2)- which means a reduction of more than 99% of bacteria after 2 hr of contact between the fabric and the bacteria titer. Figure 9-(b) shows that after 1 hr of contact with the fabric, 100% of the fungus were neutralized. Figure 9-(c) showed a reduction of 100% of the mites after 48 days of culturing with the fabric.

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Sterionizer Testing Results

The efficiency of the Sterionizer in removing different types of pollutants is presented in Table 2.

Table 2- Sterionizer efficiency tests

Substance	Substance name	Removal
Bacteria	Escherichia Coli	99%
	Escherichia Coli ATCC	91%
	Staphylococcus aureus	91%
	Pseudomonas aeruginosa	99%
	Staphylococcus aureus (MRSA)	99%
Fungus	Aspergillus Niger	97%
	Candida albicans	36%
	Dichobotrys abundans	90%
	Penicillium	95%
Mold	Cladosporium cladosporioides	97%
Spores	Bacillus subtilis var Niger	89%
Viruses	Influenza H1N1	99%
	Influenza H5N1	99%

Table 2 shows that the Sterionizer decreased the amounts of bacteria for at least 1 order of magnitude (more than 90%) for all the strains tested. It also decreased the amounts of fungus for at least 36% and the amounts of mold, spores, and viruses for at least 89% for all the tested strains.

Antibacterial Testing Results

The antibacterial efficiency of the different treatment components of the Aura system is presented in Figure 10:

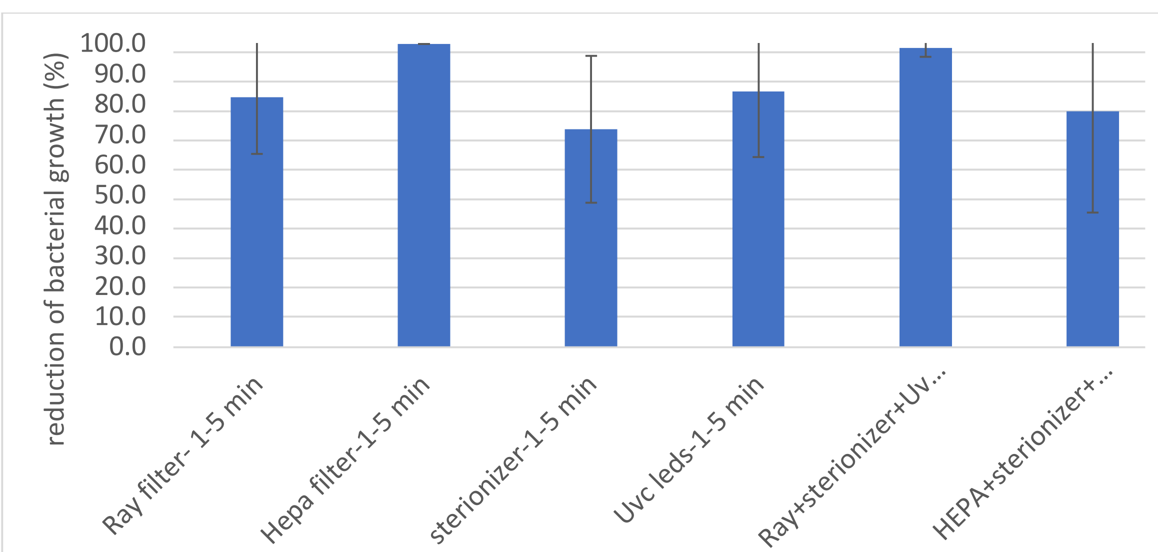

Figure 10- average bacterial reduction efficiency

As shown in Figure 10, the most efficient treatments based on these results are the HEPA treatment alone (100% reduction) and the combination of Ray filter+ Sterionizer+ UVc LEDs (98.7%). The Ray filter™ alone had an efficiency of about 82.5%, the UVc LEDs – a 84.5% reduction and the Sterionizer was the least efficient with a reduction of 72%. The HEPA+ Sterionizer + UVc LEDs was only 77.8% efficient with a large standard deviation, a result that doesn't match the other results.

The reduction efficiency of yeast and mold of the different treatment components of the Aura system is presented in Figure 11:

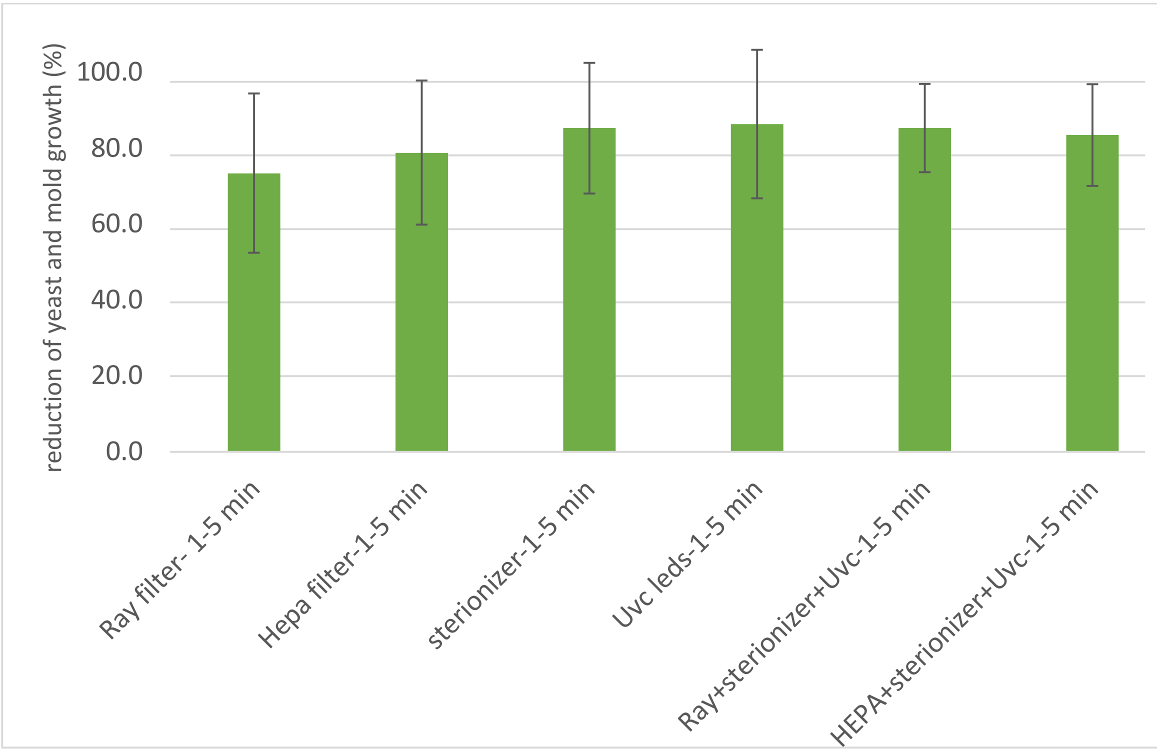

Figure 11- average yeast and mold reduction efficiency

The results presented in Figure 11 for the efficacy reduction of yeast and mold show a different scenario- all the treatments have the efficiency of 73-86%. The Ray filter™ and the HEPA filter alone show a reduction of 73.5-78 %. The most efficient treatments are the UVc alone (86.4%), the Sterionizer alone (85.3%) and the combination of Ray filter + Sterionizer + UVc LEDs (85.4%).

Examples of the plates after incubation are presented in Figures 12-13:

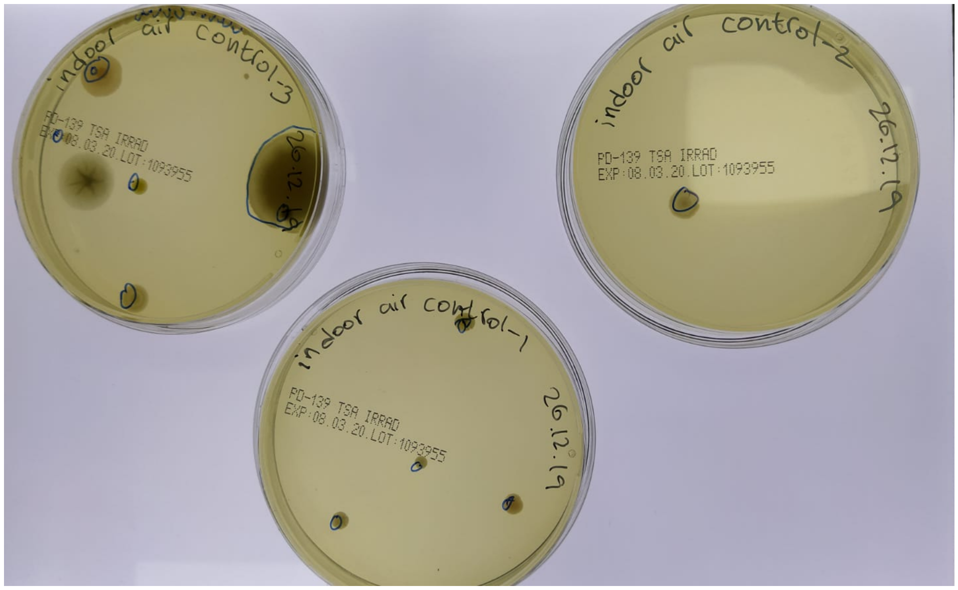

Figure 12: incubation results of the control plates on December 31st,2019

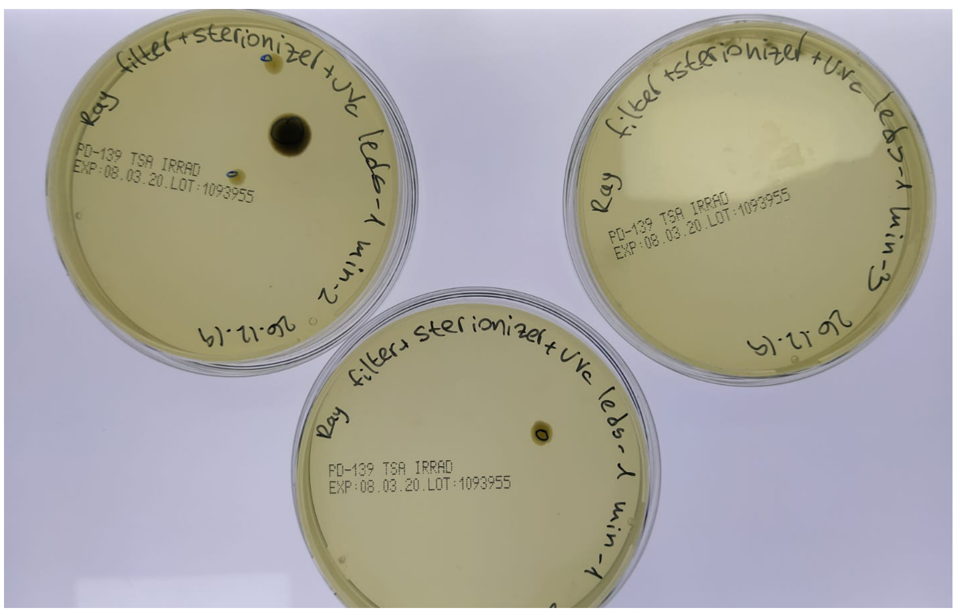

Figure 13: incubation results of the Ray filter+ Sterionizer+ UVc LEDs plates on December 31st,2019

Conclusions

- Carbon dioxide has to be measured directly (preferably by an NDIR sensor). The equivalent CO_2 measurement isn't sensitive enough for measuring changes in CO_2, especially those that are not from human breath source.
- There is significant variability in the performance of different tVOC sensors. We managed to find a sensor with good correlation to the lab results.
- There is also significant variability in the performance of dust sensors (all the sensors tested were light scattering sensors).
- Our smart fabric showed good results in decreasing the amount of bacteria, viruses, and mold when coming in contact with a liquid titer.
- The sterionizer also showed good results in decreasing the amount of bacteria, viruses, mold, spores, and fungus.
- Our Ray filter ™ alone showed good results in reduction of bacteria (83%) and yeast & mold (74%) when testing the filter in indoor air.
- The Sterionizer also showed good results in the bacterial reduction tests (72%) and yeast & mold reduction (85%).
- The UVc LEDs showed good results, as well as 84% of bacterial reduction efficiency and 86% of yeast and mold reduction.
- The overall efficiency of the whole AURA system is 99% of bacteria reduction and 86% of yeast and mold reduction.




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