

## CONFIDENTIAL

### ANALYSIS OF MOLEKULE AIR PURIFIER BASED ON MOLEKULE'S PUBLISHED INFORMATION

I have studied the Molekule website, and here are some of my observations.

1. To the best of my knowledge, **PECO** is not a scientifically recognized technology. It is a name that Molekule invented. Molekule uses a combination of filters and PCO (Photo-catalytic Oxidation) as their technology. They embed their filter with particles of TiO<sub>2</sub> (Titanium Dioxide). They irradiate the filter with UV-A light, which activates the TiO<sub>2</sub> and causes destruction of microbial and chemical compounds, which come in touch with the irradiated TiO<sub>2</sub>. As I have explained in other write-ups, in general, PCO is not a very efficient stand-alone method for air purification because of the contaminants' required contact with the irradiated TiO<sub>2</sub>. Scientific studies conducted on PCO purifiers have shown that at best only 10% of the contaminants actually touch the photo-catalyst with each pass of the air. As such, the same air has to be re-circulated through the purifier many times to achieve greater contaminant reduction. In contrast, the CVVA purifier destroys 100% of all airborne microbes with each pass through its Kill Chamber. We can draw this conclusion by analyzing the Intertek test results, which were achieved in a given size test chamber and sampled every 15 minutes. In these tests, we destroyed 1.8 billion Penicillium mold spores in a 4-hour period, which amounts to a continuous reduction of 7.2 million mold spores for each minute of operation. In contrast, Molekule advertises the destruction of 3.4 million mold spores in 50 minutes of operation.

UV-A is primarily used in PCO air purifiers because it is easy to produce and is not destructive to the materials used within the purifier. However, UV-A by itself has zero effect on the reduction of microbial and chemical compounds. In contrast, UV-C by itself, which we use within our unit, is most effective in the destruction of microbial compounds, and under certain conditions, chemical compounds. Within our unit, air contaminants do not have to touch the UV light source or any part of the chamber. Every particle that moves through our Kill Chamber is affected simply by being exposed to the light.

Having said all this, Molekule does publish what appear to be some fairly impressive test results, especially for a PCO stand-alone air purifier.

2. Based on the data that Molekule has published on their website, it is virtually impossible to do an accurate evaluation of the effectiveness of their unit, or any comparison with ClearWave Air.

Molekule lists test results for VOCs, Bacteria, Mold, Viruses and Allergens. In each case, they show the number of contaminants destroyed in a given period of time. However, they give no indication of the size of the test chamber or the concentration of the organisms. I have to use some speculation in order to give you an understanding of the significance of this.

For instance, they show that they destroyed 9.7 million e. coli bacteria in 5 minutes. Let's assume this test was conducted within a chamber that is slightly larger than the Molekule unit. At Molekule's high flow rate of 80 cubic feet/minute, the air containing the 9.7 million e. coli bacteria would pass through the Molekule purifier hundreds of times during that 5 minute period. Even if the purifier would destroy only 1% of the bacteria passing through it in each pass, you would achieve the 9.7 million reduction that they show within the 5 minutes. Obviously, if this test were conducted in a much larger test chamber or in an actual room, it would take proportionately longer periods of time to achieve reduction. The same is true for the other test results that they published. The reason that we used Intertek Laboratories is because they use a standardized test protocol that cannot be modified. As such, a true comparison can be drawn between all air purifiers that were tested under this same protocol.

Without a standardized protocol, you can always create a test scenario that favors your product when in fact this scenario may have no real life significance. One well-known example of this is the widely accepted CADR standard, which was written by and for the HEPA filter industry. The standard shows the performance of a brand new filter during the first 20 minutes of operation, which obviously gives you no indication of its real-life performance.

**Paper: Determination of the Transformair System's Efficacy against Various Bioaerosols**

1. This paper reveals that the tests were conducted on a "Transformair System" with a substantially different internal construction than the current Molekule unit. Based on these tests, no accurate conclusion can be drawn for the performance of the Molekule unit.
2. Page 7 of 24 of this paper shows charts of the particle size of the various organisms tested. The size of these organisms ranges from approximately 0.5 nanometers ( $\mu\text{m}$ ) up to 20 $\mu\text{m}$ . HEPA filters are capable of retaining particles as small as 1 $\mu\text{m}$ . As such, we can assume that the claimed reduction of organisms in this test is entirely due to Molekule's HEPA filter without any contribution of PCO. The test results would likely have been identical if PCO was not activated.
3. Page 12 and 13 of 24 shows Theoretical Multi-Pass Efficiency in a Sealed Room based upon their Single-Pass test results. This is supposed to show the actual efficiency of their purifier within a given room. In other words, How well does it perform over a period of several hours/days in reducing contaminants within a room of a known size? This would actually be the single most relevant test they could have conducted for showing the efficacy of their air purifier. However, they choose to give us a theoretical calculation knowing that in an actual multi-pass test the HEPA filter quickly becomes clogged and its efficiency dramatically drops off. As such, I believe their theoretical multi-pass calculations are greatly flawed based upon the known characteristics of HEPA filters. The HEPA industry uses the CADR rating, which is based upon a brand new filter's performance during the first twenty minutes of its operation.

**Paper: Kill Kinetics Determination for the TransformAir®'s Photocatalytic Coated Filter Media when Exposure to UV-A Light Source**

1. In studying the available data, it becomes apparent that Molekule is basically a HEPA filter, which captures various contaminants on its surface. However, due to the addition of PCO technology, some of the captured contaminants are destroyed on the filter surface improving the overall efficiency.
2. Molekule's HEPA filter material is impregnated with a limited number of nano particles of TiO<sub>2</sub> (Titanium Dioxide). Since these nano particles are solids, obviously the number of these particles is limited so that air can still freely flow through the un-impregnated filter material. Where the UVA light source irradiates these nano particles, contaminants are destroyed. However, contaminants must actually touch the TiO<sub>2</sub> particles for this destruction to occur. Any contaminants that accumulate between the nano particles will not be destroyed and will begin to clog the filter. That is why frequent Molekule filter replacement is required. As air flows through the filter, more and more contaminants are added, some of which are destroyed and others that accumulate on the open filter media.
3. This paper addresses the tests that were conducted to prove Molekule PECO technology's ability to destroy contaminants captured by the filter and reduce their accumulation. The paper provides graphs that show the contaminant count on a control filter without PCO and on a Molekule filter with PCO activated. At first sight of these graphs, I was quite impressed.

I did not expect more than perhaps a 10% difference between the two. However, as I read more details, it became clear that the tests conducted had very little relevance to the real-life operation of a Molekule unit. As before, these tests were conducted on a TransformAir unit, which is constructed substantially different from the Molekule unit.

4. First of all, the tests were not actually conducted in an operational unit. According to the write-up, "This study was performed using 47mm diameter swatches cut from the filter media used in the Transformair unit." "Eighteen filter swatches were exposed to a generated bioaerosol for 2 minutes to seed the swatches with a known quantity of cells. Nine uncoated filter media samples were used as the controls and nine photo-catalytically coated media swatches were used for the controlled UV-A exposures." Then all 18 swatches were exposed to the UV-A light source for a period of 20 minutes. After that, the filter swatches were analyzed, and the results showed that the PCO coated swatches had less microbial growth on them than the non-PCO coated swatches. Let me try to put this test into simple terms:

- These swatches were infused with a known number of live organisms.
- They were placed in a sterile chamber with the UV-A source turned on for a period of 20 minutes, during which time, no additional organisms were added.
- These flat swatches had direct exposure to the UV-A source, which is very much unlike the real-life Molekule scenario where the pleated filter media receives only partial light exposure.
- The TiO<sub>2</sub> coated swatches were exposed to UV-A light for 20 minutes without the addition of more contaminants.
- In a real-life scenario where non-sterile air continually flows through the filter media, contaminants will continually be added to the filter media.
- The contaminants that touch the nano particles will be destroyed, and the contaminants surrounding the nano particles will build up. As a result, the contaminant level on the filter media will continue to increase.
- This is another one of those tests that does not remotely resemble the real-life operation of a Molekule air purifier.

### **Natural Decay**

1. In an environment that is conducive to life, all organisms will grow and multiply. For instance, mold spores may attach to an air filter media, grow and multiply as the filter device continues to feed them moisture, oxygen and nutrients in the form of other organisms. Inversely, life organisms will rapidly die off in a sterile environment without nutrients. This die-off is called natural decay.

2. As such, all legitimate tests of air purification methods against life organisms must take natural decay into account. As you can see in the ClearWave Air test reports, Intertek Laboratories conducts identical tests with and without the air purifier. It then compares the air purifier's performance to the natural decay performance giving an accurate picture of the purifier's effectiveness. This is unlike test reports often advertised by competitors that say, "Our air purifier killed 10 million mold spores in a sterile chamber within 5 hours." The fact is that these 10 million mold spores in a sterile chamber would have died in a 5-hour period even without the influence of the air purifier.

3. Nowhere within the many pages of papers and test reports written about Molekule is there any mention of natural decay. This is one more reason why it is not possible to draw any accurate conclusions about the real-life performance of the Molekule air purifier.

## Conclusion and Comparison to ClearWave Air

1. The purpose of any tests conducted on an air purification device is to determine the performance of this device in an actual real-life situation in order to answer the essential question:

“How will this device improve the quality of air I breathe in my home in the short and long run?” The tests and write-ups that Molekule has published certainly do not answer that question in an understandable way to a layperson. These papers are full of information, much of it irrelevant to the essential question. Each portion of the tests that were conducted seems to have been tailored to achieve a positive result, regardless of whether that result had any relevance to the essential question. There seems to be no continuum among the various portions of the tests. It appears like a large puzzle in which each piece looks somewhat attractive, but there is no way of putting the pieces together into a sensible picture. A layperson could conclude that, “I am not a scientist, so I do not understand all these confusing writings; but since they all have a positive outcome, the product must be excellent.” Even with my decades of experience in this field, I had to reread these papers numerous times to begin to get an understanding of what they are all about. It is apparent that these tests were not conducted according to a standardized protocol, which would allow for a side-by-side comparison to any other product tested under that same protocol.

In contrast, ClearWave Air primarily publishes test results that were obtained by independent institutions according to a standardized protocol. The test reports by Intertek are relevant and understandable even to most laypersons with very little additional explanation.

2. As I outlined in the above paragraphs, Molekule lists a lot of 99% performance results. However, they do not disclose the details of how these results were obtained. As such, it is impossible to draw any conclusions on how their unit will perform in an actual living environment. Even their graphs, which show a reduction over time of microbial and chemical compounds, do not disclose the relevant details of the test, including the size of the chamber they were tested in, the concentration of the contaminants, or the affects of natural decay, etc. As such, these results are irrelevant to answering the essential question.

In contrast, ClearWave Air discloses all these details with each test result.

3. As outlined above, Molekule publishes their “single-pass” test results. However, considering the hundreds of thousands of dollars they have spent in testing, it is noteworthy that they do not publish any “multi-pass” test results, which would give you an indication on how their unit would perform after repeated operation over a period of hours or days. Instead, they publish “theoretical calculations for multi-pass efficiency in a sealed room.” This test would have been the least expensive and most relevant test they could have performed to answer the essential question. It is my suspicion that Molekule has conducted such tests, but their air purifier showed significant performance drop-off after several hours or days of operation. As such, they choose to publish only theoretical calculations, which look favorable to them.

In contrast, ClearWave Air has conducted dozens of separate mold spore tests using \$10 Petri dishes in various enclosures, including bedrooms, greenhouses, motor homes, crawl spaces, basements, etc. The test requires the one-hour placement of a Petri dish in an untreated room, followed by another one-hour Petri dish placement in the same room after several days of operation of the air purifier. A side-by-side comparison of the incubated Petri dish photos before and after treatment with the CWA unit requires virtually no explanation and evokes amazement even by most laypersons. ClearWave Air's website shows a photograph of side-by-side Petri dishes that were obtained by testing the air in a 40' motor home. It also shows the amazing results of tests conducted in a highly mold-contaminated home near Mission Beach in San Diego.

4. Based on all of Molekule's published data, I suggest the following:
- Molekule is an "improved HEPA filter." The improvement is due to the addition of PCO technology that reduces—not eliminates the clogging and bio fouling of the filter media, which is one of the major weaknesses of HEPA filters.
  - Molekule does not qualify as a standalone PCO air purifier since the PCO technology is not employed to destroy contaminants in the air, but rather reduce the contaminant load on the filter media.
  - In order to get a true picture of its long-term performance, a new Molekule unit would have to be tested at Intertek Laboratories according to their standardized protocols, and should be retested after 30 days of continuous operation in an actual living environment. I believe the results would show considerably less performance than they claim, including a dramatic performance drop-off after prolonged operation.

In contrast, ClearWave Air is a pure air sanitizer, which utterly destroys airborne microbial content and reduces many chemical and odorous compounds within its proprietary Kill Chamber, as proven by numerous Intertek tests.

- ClearWave Air includes an activated carbon pre-filter, intentionally designed with an open porosity to allow microbial contaminants to pass through to the Kill Chamber rather than being captured and contained in the filter. The filter primarily exists to prevent dust and larger particles to enter the unit. Additionally, the activated carbon aids in reducing VOCs and odorous compounds.
- The ClearWave Air purifier performance does not diminish over time. The unit continually self-diagnoses. It will perform as well after 3 years of continuous operation as it did the moment it was first plugged in assuming it has frequent inexpensive filter replacements and it is in perfect operating condition, as evidenced by the visible blue lights.

ClearWave Air has been successfully testing actual prototypes with PCO technology added to its air purifiers for over two years. Several patents have already been granted, and one more very important patent has been applied for. The addition of PCO technology will expand ClearWave Air's purification capabilities to allow for even greater microbial reduction and significant additional chemical and odorous compound reduction. The new unit is expected to go into production before the end of 2018.