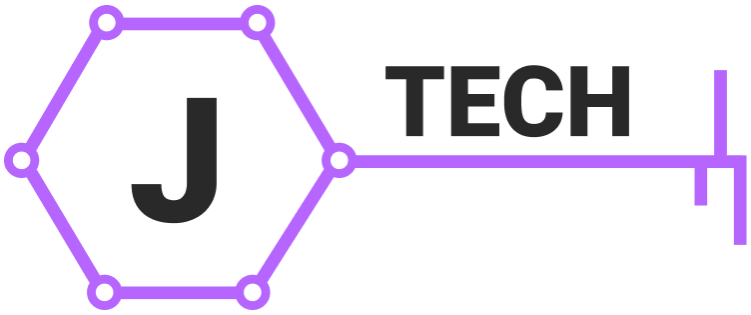

Technological-Scientific Risk Assessment Report

Enterprise name: *The Company*

Sample Report

Technology Type: Consumer electronics, Nanotechnology
Geographic Region: Global

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1. Recommendation and Findings

The function of the "*Technological-Scientific Risk Assessment Report*" is to identify the potential for development of proposed technological solution and associated technological risks. We will look at three areas – technological and scientific approach, existing products, and relevant competitive patents. We also provide an overall recommendation based on the factors outlined in the individual sections of the report.

Our recommendation is based on critical examination of:

- The materials provided by the *company*;
- R&D and academic articles found *via* Web searches;
- Patents listed on the Patent Online servers
- Products found *via* Web and literature searches.

The levels of associated risk at each section are: Low Risk, Medium risk and High risk.

Recommendation: HIGH RISK for product to achieve declared performance

The *company* wishes to develop compact air purifier using nano-technology to eliminate mold, airborne bacteria, virus, and toxic chemicals without the use of a filter. The proposed device should be the size of a beverage can. The operation principle of the proposed technology is photo-catalytic activity of TiO_2 nanoparticles under UV illumination that destroys toxic chemical and bacteria. Accordingly to the *company*, the implementation of nano-technological solution is much better than presently used High Efficiency Particulate Air (HEPA) filters that trap bacteria and mold but are a perfect place for bacteria and mold to grow which is a big disadvantage.

The key findings are:

1. **Technology maturity level:** The developers have completed proof-of-concept. However, its efficiency in real life conditions is under question.
2. **Intellectual property:** The intellectual property is protected by a (*patent number)* granted in (*country name)*.
3. **Possible competing products:** There are a large number of compact air purifiers available on the market. However, most of them are based on HEPA filters, some of them have UV sanitizer and the rest are based on other technologies.

4. **Possible competing patents:** In the patents and published applications search we found technologies relatively similar to the *company's* technological approach.

2. Brief Description

The *company* is developing a compact air purifier device using nanotechnology to destroy mold, airborne bacteria, virus and toxic chemicals. The device of the *company* doesn't have a filter that need to be replaced as in the competitors' products.

3. Description of Technological Approach

The proposed technological solution is based on photo-catalytic activity of TiO_2 nanoparticles under UV illumination to eliminate mold, airborne bacteria, virus, and toxic chemicals.

In the proposed device nanoparticles are deposited on top of vertical blades that are located inside the device. The *company* issued a patent that was granted in *country name* (comment: outside US) and protects the way the device deals with parallel to vertical blades air flow in order to increase air retention.

4. Technological Approach Analysis

Number of concerns arise regarding the declared performance of the proposed device:

1. Power consumption and efficiency
    a. The *company* provided test results of the device performance for toxic chemicals and bacteria removal in a closed chamber with a volume of 1 cubic meter. They use this result to prove that the device will work in real life conditions, but the tested volume is significantly smaller than proposed real usage conditions like living room or car.
    b. The proposed device power consumption is 2.5W, according to the *company* the power consumption of 2.5 W should be enough to operate simultaneously UV source and fan. One UV source typically consumes 1-3W meaning that the power left to operate the fan is about 1W. Fan with this power can circulate about 0.1

cubic meter of air per minute. For comparison a small room of 10 square meter has 30 cubic meters of air.

From this analysis we can conclude that the promised performance can't be made with the proposed device, and the device will need to be altered to achieve declared performance.

2. Photo-catalytic activity efficiency during operation

   It has been widely described in academic literature (as will be shown below) that photo-catalytic TiO_2 nanoparticles can effectively remove toxic chemicals and bacteria from the air. However, this strongly depends on UV power and air interaction with photo-catalytic surface. First of all the air flow parallel to vertical blades with photo-catalytic surface reduces significantly the purification efficiency due to low air-to-surface contact volume. Secondary, the UV illumination power from 1-2W UV light source is very low (typically in tens of mW). This means that there might be not enough light power to activate sufficient reaction to destroy toxic chemicals and bacteria.

3. Absence of filter in the device

   The air contains not only toxic chemicals and bacteria but also dust. The dust will sink on the photo-catalytic blades and will potentially degrade device performance over time. This must be taken into consideration in the development stage.

4. Ozone generation

   UV light can generate ozone gas that is toxic. The *company* doesn't show any results, and doesn't discuss this subject. As a consumer device, the subject of ozone generation should be noticed by the *company*.

Conclusion: Based on our *Technological Approach Analysis* we conclude **HIGH RISK**- From the technological perspective, the device is based upon proven innovative approach based on photo-catalytic activity of TiO_2 nanoparticles to eliminate mold, airborne bacteria, virus, and toxic chemicals. However, its performance in present design and specifications will probably not meet the declared performance by the *company* at this stage.

5. Academic/ R&D Search

A search of Google Scholar and ISI Web of Knowledge and free google search was conducted using the query “TiO2 photo catalysis”, “air treatment”, “TiO2 AND air treatment”, and “TiO2 AND air treatment AND bacteria”, “Air purifier”, “TiO2 AND air purifier” and other combinations of similar meaning. We also examined the literature for R&D via a Web search.

Examples of relevant articles and papers identified

Project	Institution and period	Relevance/description	Web site
The Viability of Photocatalysis for Air Purification	United Technologies Research Center, 2015	Review on TiO_2 phot-catalytic effect in air purification.[1]	http://www.mdpi.com/1420-3049/20/1/1319/htm
Effectiveness of Titanium Dioxide Photocatalyst Filters for Controlling Bioaerosols	Graduate Institute of Environmental Health, Taiwan, China, 2003	Present research investigates TiO_2 phot-catalytic effect in air purification from bacteria under air flow conditions. The results show low effectiveness.[2]	https://www.tandfonline.com/doi/abs/10.1080/02786820300951
Antibacterial Activity of TiO2 Photocatalyst Alone or in Coatings on *E. coli*: The Influence of Methodological Aspects	Université de Toulouse, France, 2014	Present research investigates TiO_2 phot-catalytic effect in air purification from bacteria under stable air conditions without air flow. The results show high effectiveness.[3]	http://www.mdpi.com/2079-6412/4/3/670

A very large number of scientific papers have been published on efficiency of photo-catalytic TiO_2 nanoparticles for air purification under UV illumination conditions. The first entry[1] provides a

thoughtful introduction to photo-catalytic air purification process and its efficiency from chemical and kinetic point of view. The authors show that a better efficiency gained under higher air humidity conditions, and slower air flow velocity.

Entry two[2] describes the effectiveness of photo-catalytic TiO_2 nanoparticles for air purification from different types of bacteria under UV illumination conditions at different air flow velocities. In the presented experiments an air with a constant amount of bacteria was passed *via* air purification system at different velocities. The results of performed experiments show low air purification efficiency for bacteria due to short bacteria to photo-catalytic layer interaction time.

Entry three[3] describes the effectiveness of photo-catalytic TiO_2 nanoparticles for air purification from different types of bacteria under UV illumination conditions and without air flow. In their work the authors placed some amount of bacteria and a layer with photo-catalytic TiO_2 nanoparticles inside a closed chamber. The provided experiment showed that good air purification efficiency has been achieved after at least two hours.

Conclusion: Based on our *Academic/ R&D Search* we conclude **MEDIUM RISK**. The efficiency Of TiO_2 nanoparticles and UV light for air purification is a well-known fact and was thoroughly researched. All research show that the retention time of air upon the TiO_2 layer plays the most important role in the efficiency of killing bacteria, and that is should be long. This limits devices as it lowers the volume of air a small device can purify efficiently. In any case, the technology should work, with performance as the main issue.[2]

6. Patent Search

We search the following data sets: European Patents and Applications from the European Patent Office; and US Patents and Applications from the US Patent and Trademark Office; WIPO PCT Publications, which contains abstracts, full documents images, and full text from over a hundred member countries of the Patent Cooperation Treaty.

Searching these data sets simultaneously often does lead to multiple counts of the same patent, as both the application and patent may be retrieved or the item can show up in multiple databases. This procedure highlights applicants who file, pursue the patent, and protect it in multiple

jurisdictions and the presumption is a patent protected in multiple jurisdictions is more important to its owners than one which is not.

Given this procedure, the following patent or applications were found using the following search string “Air-cleaning apparatus”. Overall, the string produced 1606 hits.

The following patents and patent applications indicate kinds and range of technology that show up in the patent literature. We emphasize that we look at patents from the standpoint of market competition and technology. We have no opinion on the patentability of your technology or strength of your existing patent. Please consult with qualified legal counsel for opinions on the client’s freedom to operate and extent of Intellectual Property protection. Material in quotes is from the patent abstract unless otherwise noted.

Examples of relevant patents and patent applications identified

Patent or patent application #	**Patent title**	**Date**	**Relevance**	**Assignee**
US9101904B2	Air purification system using ultraviolet light emitting diodes and photocatalyst-coated supports	Aug. 11, 2015	Air cleaning chamber that comprised of TiO_2 photo-catalyst deposited on top of parallel to air flow supports. The air flow direction was chosen to increase retention time.	Honeywell International INC.
US9974881B2	Air purifier using ultraviolet rays	May. 22, 2018	Air cleaning apparatus that use TiO_2 photo-catalyst deposited on top a structure having increased air retention time	Seoul Viosys Co., LTD
US2013/0142692A1 (abandoned)	Method and apparatus for purification of air	Jun. 6, 2013	Apparatus for air purification using TiO_2 photo-catalytic layer activated with UVC light.	Mohamed H. Tarifi

The *company* patent (*patent number*) was granted in (*country*) (comment: *not US*). The patent describes single body air cleaning apparatus based on photo-catalytic layer and ultraviolet light source about. Photo-catalyst layer is disposed in the accommodating space, and this photo-catalyst layer has a maximum surface area of the side wall system to the main flow direction of the air parallel to increase air flow.

Patent US9101904B2 describes an air cleaning system comprised from an UV LED and a photo catalytic unit that contact the airflow that passes across or through the support. Where the photo catalytic chamber and the support plates are parallel to each other. The LED is comprised of an array of LEDs. The air purification systems design described in US9101904B2 differ from the *company* patent as it describes the uniqueness of the support structure, although the systems according to their claims were design to maximize air retention time as the *company* patent.

Patent US9974881B2 describes a case having an air inlet and an air outlet, a fan disposed inside the case and adjacent the air inlet, an ultraviolet (UV) light emitting diode (LED) unit and a filter unit arranged inside the case over the fan along a flow path of air, and a fluid control structure disposed inside the case between the fan and the filter unit. The fluid control structure controls an air flow along the flow path of air between an outlet of the fan and the filter unit. The patent don't protect photo catalytic element, but takes special care to protect the way the air is designed to flow inside the unit and through the filter.

Patents application US2013/0142692A1 describe air purification system based on photo-catalytic layer comprised of both TiO2 and activated carbon. The filter media adapted to absorb pollutants from the air. TiO_2 immobilized on the filter media. Two UV lamps are used, first UV lamp disposed on the upstream side of the filter, and a second UV lamp disposed on the downstream side of the filter. In another embodiment an additional activated carbon filter absorbs the pollutants from air while TiO_2 layer immobilized on the activated carbon. In claims they protect a system that utilize two UV lamps and layers of TiO_2 and activated carbon, separately or both.

Conclusion: Based on our *Patent Search* we conclude **MEDIUM RISK**. There are many patents that talk about air purification systems that utilize both UV light and TiO_2 photo catalytic layer. The

uniqueness of the *company* technology is in the configuration between the photo catalytic layer and the air flow, but we have not found any strong evidence that this attribute improves on any other invention. The *company's* patent was granted outside US and there is a risk that the *company* will have difficulties to achieve the same result in the US.

We emphasize we are not patent attorneys and thus our analysis focuses on marketability. We recommend that the client consult with qualified legal counsel regarding opinions on freedom to operate and extent of Intellectual Property protection.

7. Product Search

We searched Google, Amazon and the Web for relevant products using the terms "photocatalytic oxidation air purifier AND TiO2 AND producers", "photocatalytic oxidation air purifier AND TiO2", "TiO2 air purifier AND producers", "UV TiO2 air purifier", and "photocatalytic AND air purifier"

Examples of relevant products identified:

Product name	Manufacture	Relevance/description	Website
Mobile UV PCO Sanifiers	**Air Oasis**	Air Oasis manufactures and sells Compact air purifier suitable for small spaces (as well as other larger air purifiers). Claim to have air filtration and air and surface sanitation capabilities.	https://www.air-oasis-uv-pco-sanitizers.com
Airocide	**Airocide**	Airocide's fan draws in airborne organic pathogens like allergy triggers, mold spores and fumes from household chemicals (VOCs) and slows them down, dispersing them across a densely	http://www.airocide.com

		packed matrix of hollow glass tubes.	
Product line: Airpure R600, T600, V600	**Airpure**	Air purifiers suitable for large spaces. The air purifier is based on proven HEPA filter technology with an additional carbon filter.	https://airpura.com/

Air Oasis claim to have the most advanced hydrated photo catalytic oxidation technology that eliminates bacteria, viruses, molds, odors and volatile organic compounds. They utilize a state-of-the-art, patented high-performance metallic catalyst, nano-technology and photo catalytic oxidation technology unique to any product currently on the market today, TiO_2. They base of their technology is Advanced Hydrated Photo catalytic Oxidation Cell that claimed to be superior to older standalone UV (like the *company* technology). The smallest Air Oasis purifier that is the mobile version consumes 11W of power (four times as much). On their website they also talk about problem of Ozone generation due to UV that is reduced in their device due to the technology they use.

Airocide air filtration system is a larger but still portable air filtration system that utilize a special Photo catalytic Oxidation Cell that is much larger in size. They have a very clever way to disperse the air sucked by the system for optimum dispersion across the catalytic cell. The Airocide uses 60W of electricity, substantially higher than the proposed technology, for the same claimed results. As the Air Oasis device, they mention that no ozone is generated in their system due to their design. Two important points to note are:

a. The Airocode reaction chamber, the photo catalytic element must be replaced once a year, due to carbon residue that is the result of the photo catalytic process.
b. The Aircode is listed as a Class II medical device, this is the only mention of such we have observed, and could be done for marketing reasons and not technological. But do raise further questions.

The third entry on the list represents the standard technology that is used in air purifiers, it's based upon a high efficiency particulate air (HEPA) filter with an additional carbon filter for better

performance. For technological comparison, the HEPA based device requires 120W of electricity. The HEPA technology is based on circulating high flow of air through the filter to achieve high filtration. This compared to the photo-catalytic based devices that are much more efficient.

Conclusion: Based on our *Product Search* we conclude **MEDIUM RISK**, there are few competing technologies including the well-known and used HEPA, as well as Ionic and charcoal filter approaches. The photo-catalytic approach shows to be the most efficient of them all. The risks is derived through the technological roadmap of the *company* that declares performance comparable to the one listed below with lower power consumption, and does not take into account ozone generation and the need to change the catalytic filter.

8. References

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3. Verdier, T., Coutand, M., Bertron, A. & Roques, C. Antibacterial Activity of TiO2 Photocatalyst Alone or in Coatings on E. coli: The Influence of Methodological Aspects. *Coatings* **4,** 670–686 (2014). http://www.mdpi.com/2079-6412/4/3/670