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Efficacy of a Nonthermal Plasma Technology in Reducing Infection Risk and Improving Air Quality in an Active Hotel Environment

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Abstract

Antimicrobial resistant bacteria and viruses pose an ongoing and increasing health challenge to hotels and hospitality facilities given the large number of interactions between and among guests, staff and vendors in common areas during hotel stays. In addition, these bacteria and viruses pose a difficult challenge in the prevention of cross-transmission and contamination in guest rooms. The White House hosted a virtual event titled "Let's Clear the Air on COVID" on March 29, 2022, at which The White House emphasized that indoor air poses the biggest risk for coronavirus infections and future pandemic challenges. The objective of this study was to evaluate the effectiveness of AIRPHX nonthermal plasma technology for reducing air and surface populations of microorganisms in a full-service hotel, including common areas and guest rooms. AIRPHX uses a cost effective, proprietary nonthermal plasma technology to create a number of oxidizing molecules that are highly effective disinfecting agents. The long-term tests were conducted in a full-service hotel managed by one of the largest global hospitality companies (The "Test Property"). The Test Property has over 450 rooms with an eight-story atrium and attached conference facilities including a configurable ballroom and several smaller conference rooms. After the initial in-treatment testing on July 17, 2020, the Test Property was being treated with three AIRPHX PA2400 units, two in the lobby and one in the conference center. The results are consistent in the lobby, conference center and guest rooms -- significant reductions in airborne and surface organisms. This conclusion is based on real world testing and pathogen reduction levels supported by independent lab results (and not simply results based on a controlled lab setting). The scalable and easily deployed nature of the AIRPHX technology appears to offer a proactive and cost-effective solution to sanitizing large and heavily trafficked facilities utilized in the hotel and hospitality industries.

Keywords: *Nonthermal Plasma Technology; AIRPHX; Indoor Air Quality; Active Hotel Environment*

Introduction

Viruses have several features that make this class of microbial agents the most likely to cause global catastrophic biological risk. Viruses possess higher capacity for genetic mutability due to both the structure of their genomes and the generation time for replication in which large numbers of progeny viruses are created each day. Additionally, the inability of a virus to be countered with a broad-spectrum antiviral, compared with bacteria, fungi, and parasites, makes viruses the more likely cause of a such a biological risk. Inside the viral class, RNA viruses merit special concern chiefly because of their higher mutability compared to DNA viruses.

The recent emergence of severe infectious diseases with pandemic potential has triggered much interest in understanding the broader pandemic threat landscape. The White House hosted a virtual event titled "Let's Clear the Air on COVID" on March 29, 2022, at which The

White House emphasized that indoor air poses the biggest risk for coronavirus infections and future pandemic challenges. The Environmental Protection Agency (EPA) also announced its Clean Air in Buildings Challenge - a tool kit for how building owners and operators can ensure better indoor air quality by (1) circulating "clean" outdoor air indoors (i.e. increased numbers of air exchanges), and (2) installing better air filtration devices. While there are potential unproven benefits to increasing the number of air exchanges, such as exhausting a portion of the airborne virus and bacteria particles in the building, there are a number of significant drawbacks associated with that approach. Although generally free of airborne virus and bacteria particles, outdoor air typically has very high levels of airborne mold spores and fungi and significantly higher levels of ozone than indoor air. Extensive testing of indoor and outdoor air by Scientific Air Solutions at over 75 locations using AIRPHX equipment demonstrates the high levels of mold and fungi contained in outdoor air and reductions of indoor levels by over 90% inside of AIRPHX treated spaces. The serious adverse effect of elevated levels of mold spores, fungi and ozone on people is well documented [1-4]. The increased cost and use of energy to heat and cool newly introduced outdoor air is substantial, making this approach environmentally problematic and economically unattractive to building owners. Finally, increased air exchanges result in the need for more frequent maintenance and replacement of air handling equipment. A cost effective and efficient air filtration and/or disinfection device is a better approach to indoor air quality.

Existing air filtration and disinfection efforts of hotels and hospitality operations have included (i) employing enhanced sanitizing procedures throughout the facility, including the use of electrostatic sprayers and chemicals, (ii) use of various passive filtration devices designed to capture airborne particulates and pathogens that pass through the filter or the facility's ductwork, including high-efficiency particulate air (HEPA) filters, electromagnetic filters and in-duct ultraviolet light (UV-C) products, and (iii) use of active disinfection products like ionizers (including bi-polar and needlepoint ionizers) and photocatalytic oxidation (PCO) devices (including those marketed as dry hydrogen peroxide) that claim to destroy viruses and bacteria in the facility (as opposed to just treating viruses and bacteria that pass through the device). Despite laboratory testing results that support claims of substantial destruction of microbes, these solutions all have significant limitations as to disinfecting efficacy and/or cost in real world applications.

Enhanced cleaning procedures through use of electrostatic sprayers and chemicals result in substantial labor and material costs. The effectiveness of this approach is limited to the thoroughness of application process, often limited by time constraints between guest room turnover, and is limited to addressing surface contamination. The many varieties of filtration products, whether deployed in air handlers or in stand-alone units, are intended to treat only air that passes through the device. Filtration devices will not be effective against any pathogens that do not pass through the filter or are too small to be captured by the filter. Active disinfecting products like ionizers and PCO devices have shown to be effective disinfecting agents in controlled laboratory tests but have very limited coverage areas (in part due to very short half-lives of ions), so scaling to cover an entire hotel or hospitality facility is cost prohibitive. No independent testing of the devices and technologies described above has been identified that establishes the disinfecting efficacy of such treatments in real world applications like an operating hotel. Each of these methods for addressing pathogens is inadequate or impractical for long-term deployment in a hotel property due to cost, inability to scale or lack of proven efficacy in large spaces.

This study evaluates the effectiveness of a nonthermal plasma technology developed by a U.S. based company, AIRPHX, in addressing pandemic risk from airborne and surface organisms throughout a large hotel, including in common areas of the hotel and guest rooms. Hotels and hospitality businesses, in particular, pose risks given the large number of guest, staff and vendor interactions in the facility. Risks are increased as transmission of pandemic organisms has been shown to occur in the airflow between guest rooms as a result of doors opening and closing and guest movement. As documented by News Medical Life Sciences, community outbreaks of imported SARS-CoV-2 Beta have occurred as a result of intra-hotel transmission in a designated quarantine hotel [5]. As documented in the journal Lancet Regional Health - Western, preventative measures such as portable particulate air filters and additional surgical masking by residents while opening doors also failed to stop intra-hotel transmission [6]. These results highlight the difficulty of reducing infection risks in a hotel, even with guests remaining within guest rooms to avoid contact with the public and staff.

As documented in this study, the scalable and easily deployed nature of the AIRPHX technology appears to offer a proactive and cost-effective solution to sanitizing large and heavily trafficked facilities utilized in the hotel and hospitality industries. This conclusion is based on real world testing and pathogen reduction levels supported by independent lab results (and not simply results based on a controlled lab setting).

AIRPHX uses a proprietary nonthermal plasma technology to create a number of oxidizing molecules that are highly effective disinfecting agents. AIRPHX technology relies on electricity to create a plasma field and the oxygen present in ambient air to produce these oxidizing molecules without using chemicals[1]. The oxidizing molecules created by AIRPHX include oxygen ions, free radicals and peroxides that are highly reactive due to the presence of an unpaired valence shell electron.

AIRPHX nonthermal plasma is created using a proprietary plasma chamber that creates a stable, non-collapsing plasma field (Figure 1). Alternative systems generate a large amount of heat due to inefficiency in production of the plasma field. AIRPHX technology does not increase the ambient temperature. Hence, AIRPHX units are classified as nonthermal plasma.

Figure 1: *AIRPHX plasma chamber.*

Measurable levels of gas-phase hydrogen peroxide (or H_2O_2), ozone and other types of oxidizing molecules are produced within the plasma chamber. The disinfection achieved by AIRPHX units outside of the unit is the result of the gas-phase hydrogen peroxide, which is different and safer than vaporized or aerosolized hydrogen peroxide. Gas-phase hydrogen peroxide has a more acute bond angle and a variable half-life measured in hours. The low levels of ozone produced by AIRPHX units are virtually eliminated prior to air exiting the unit by a patent pending catalyst. A number of other oxidizing molecules are created within the plasma chamber but do not leave it (or exist only momentarily after leaving it) due their short half-lives. These include: atomic oxygen (O), singlet oxygen (O_2 with displaced electron), hydroxyl radicals and superoxide (O^{2-}). Even though they do not as a practical matter exit the unit, within the unit they are additional highly-effective oxidizing agents for any microorganisms that pass through the units.

The technology developed by AIRPHX has a wide range of applications because of its ability to produce a highly oxidative environment within its plasma chamber and its ability to discharge molecules that have an oxidizing capacity at levels that are safe for human exposure into the environment. Treatment via the AIRPHX system attacks the virus capsid (or the capsid envelope) and bacteria cell wall allowing for complete destruction and no further RNA/DNA resistance mutation. AIRPHX technology can be scaled to any size treatment space without sacrificing treatment efficacy, and is continuous and highly effective.

Safety considerations

The low-level hydrogen peroxide (H_2O_2) byproduct of the disinfection process that occurs within an AIRPHX unit is not hazardous according to the OSHA Hazard Communication Standard 29 CFR 1910.1200. Gas-phase hydrogen peroxide is an excellent disinfecting

[1]AIRPHX believes it holds the only patents issued in the U.S. and internationally related to the generation and use of nonthermal plasma to generate disinfecting molecules.

agent with a very long half-life and occurs naturally in the air. The National Institute of Health confirms the efficacy of hydrogen peroxide: "Nonflammable, hydrogen peroxide is a powerful oxidizing agent…." Hydrogen peroxide is seen as an environmentally safe alternative to chlorine-based bleaches, as it degrades to form oxygen and water and it is generally regarded as safe (GRAS) as an anti-microbial by the Food and Drug Administration (FDA). CFR, Title 21 Part 184, Sec. 184.1366. Hydrogen peroxide has no known carcinogenic potential. Hydrogen peroxide is regulated by the Occupational Safety and Health Administration (OSHA) and the Center for Disease Control (CDC) through The National Institute for Occupational Safety and Health (NIOSH), both of which have established limits of 1.0 parts per million (ppm). Using an Interscan Hydrogen Peroxide Analyzer, AIRPHX technology generally registers levels of less than 0.01 ppm of hydrogen peroxide (1/100 the OSHA limit) to the extent hydrogen peroxide is even measurable. No CDC, Food and Drug Administration or EPA guidelines or any other studies suggest that gas-phase hydrogen peroxide at these low levels raise any health concerns.

Ozone levels are regulated by OSHA, which has generally established limits of 0.100 ppm. Ozone levels are also regulated by the California Air Resources Board (CARB), which has established more stringent limits of 0.050 ppm, measured at the output of the unit. International product testing company Intertek has confirmed that AIRPHX's CID 75k generates levels of ozone that pass CARB's stringent ozone emission standards (UL 867). And given the extremely large coverage area treated by a single AIRPHX unit, dissolved levels of ozone generated by AIRPHX units is virtually undetectable.

Materials and Methods

The long-term tests were conducted in a full-service hotel managed by one of the largest global hospitality companies (the "Test Property"). The Test Property has over 450 rooms with an eight story atrium and attached conference facilities including a configurable ballroom and several smaller conference rooms. The tests were initiated on June 25, 2020 with two AIRPHX PA2400 units installed in the lobby bar area, one AIRPHX PA2400 unit on a portable stand deployed in the conference space, and one wall mounted CID 75K unit deployed in one of the guest hallways on the fifth floor[2]. The CID 75K was removed after the first in-treatment test in order to evaluate whether the remaining PA2400 units were effectively treating the guest rooms. Direct treatment areas included the lobby, the registration desk, atrium and the conference hallway. Indirect "halo" treatment areas tested include a restaurant attached to the lobby, conference meeting rooms, fitness center on the lower level, and guest hallways and guest rooms.

Pre-treatment testing was conducted on June 20, 2020. In-treatment testing was conducted on July 17, 2020, August 7, 2020 and April 22, 2022. At the time of pre-treatment testing, the lobby was being treated with a leading bi-polar ionizer product. The pre-treatment and in-treatment testing process indicated that the ionizer technology was ineffective at reducing airborne and surface organisms. The results of the tests set forth in this paper are reductions from the microorganism levels recorded at the time the ionizer technology was removed.

The facilities management of the Test Property was on-site and able to monitor the sampling for each round of tests and confirmed no material changes were made to the air handling systems or disinfection protocols at the Test Property during the test period[3].

Volumetric air sampling

Air sampling entailed drawing 30 liters of air per sample using a MicroBio MB1 volumetric air sampler, Cantium Scientific, Clarendon Gardens, Dartford UK. Scientific Air Solutions is the North American Distributer for the MB1 and MB2 volumetric air samplers.

[2]AIRPHX advised the manager of the hotel that the number of AIRPHX units deployed would not produce optimal results given the massive treatment space (estimated at over 6 million cubic feet). The deployment of a limited number of additional AIRPHX units would be expected to improve overall results.

[3]At one point during the test period after three rounds of testing had occurred, three portable filtration devices were deployed in the lobby of the hotel, but no additional testing of air and surface microorganisms occurred until six months after the removal of the portable filtration devices.

Air samples were impinged on 15x100 mm potato dextrose agar plates acquired from Hardy Diagnostics, Santa Maria, California. Air sample morphology and enumeration was completed by Scientific Air Solutions, Turlock, California. Recorded results are normalized to colony-forming units per cubic meter of air, CFU/m^3. A colony-forming unit or CFU is a unit used in microbiology to estimate the number of bacteria or fungal cells in a sample size that are viable and/or able to multiply. Counting with colony-forming units requires culturing the microbes and counts only viable cells, in contrast with microscopic examination which counts all cells, living or dead[4].

Air quality scale for workplaces, public buildings (including hotels), schools and homes are as follows:

- < 100 CFU/m^3 is considered clean and acceptable.
- 100 to 300 CFU/m^3 is marginal.
- > 300 CFU/m^3 is not acceptable and needs corrective action.

Surface testing

Surface testing included surface swabs acquired from Solar Biologicals, Inc., Ontario, Canada. A uniform six inch by six inch square surface area is swabbed for each sample, with swab sponges forwarded to Scientific Air Solutions for enumeration. All swab samples were examined for the number of organisms and recorded as colony forming units per cubic centimeter, CFU/cm^2.

Contact surface quality scale for workplaces, public buildings (including hotels), schools and homes are as follows:

- < 5 CFU/cm^2 is considered clean and acceptable.
- 5 to 10 CFU/cm^2 is considered marginal.
- > 10 CFU/cm^2 is considered not acceptable and needs corrective action.

Treatment

For both the direct and "halo" treatment spaces, sample locations were mapped and noted with either air sampling or surface swabbing. Upon completion of pre-treatment sampling, the AIRPHX PA2400 units and the CID 75K unit were placed in the treatment areas and activated. The AIRPHX units were allowed to operate continuously between June 25, 2020 and April 22, 2022. At the dates identified above, in-treatment volumetric air samples and surface swabbing were taken in the same locations as the pre-treatment sampling. External air samples were taken to understand the influence of the supplied air to the two test locations. The results are given in table 1 and 2.

Results and Discussion

Prior to deploying AIRPHX units, the Test Property was evaluated and found the total volume of treatment space to be several million cubic feet. For purposes of this study, initially three PA2400s and one CID 75k were deployed even though AIRPHX concluded that peak efficacy of the Test Property would likely require additional units. To ensure consistency, test samples were taken between 9:00 am and 11:00 am for each test report.

[4]Although the predominant organisms noted in the test reports are fungi, previous testing results by Scientific Air Solutions show bacteria, viruses and protozoa are eliminated as effectively as fungi. The oxidizing molecules generated by AIRPHX technology are effective on gram +, gram – bacteria, protozoa, spores and viruses.

Lobby area

Two AIRPHX devices were located above the lobby bar. The lobby includes the lobby bar, lounge area, the registration desk and an open eight story atrium. "Halo" areas adjacent to the lobby but not receiving direct treatment included a full-service restaurant the elevator lobby and the elevators themselves. A total of twenty (20) air samples and nine (9) surface swabs were taken (See figure 2).

Figure 2

Pre-treatment sampling was conducted on June 20, 2020. AIRPHX units were deployed on June 25, 2020. Initial in-treatment sampling was conducted on July 17, 2020, representing 22 days of treatment. Additional in-treatment sampling was conducted August 7, 2020, and then, most recently with the Test Property at full occupancy, on April 22, 2022.

Volumetric air samples

1. Pre-treatment air samples ranged from 308 to 506 CFU/m^3 with an average of 430 CFU/m^3.

2. Initial in-treatment results ranged from 33 to 300 CFU/m^3, an average of 70 CFU/m^3 and a reduction of 84% thus showing the AIRPHX system reduced the bioburden within the direct lobby treatment space including on floors 2-8 of the open atrium. The restaurant adjacent to the lobby experienced similar reductions in airborne organisms indicated that the oxidizing molecules created by AIRPHX effectively sanitized the restaurant as well as the lobby.

3. Additional in-treatment results including sampling on April 22, 2022 show results ranged from 60 to 78 CFU/m^3, an average of 67 CFU/m^3 and a reduction of 84% thus showing the AIRPHX system continued to be effective even with the Test Property at full occupancy.

Surface contact "swabs"

1. Pre-treatment surface swab results were 33.6 CFU/cm^2.

2. Initial In-treatment surface testing results revealed an average count of 2.6 CFU/cm^2, yielding a 92% reduction during the initial treatment phase.

3. Additional in-treatment results surface testing results on April 22, 2022 revealed an average count of 1.6 CFU/cm^2, yielding a 95% reduction showing the AIRPHX system continued to be effective even with the Test Property at full occupancy.

4. As shown in the MEMO lines, the positive effects of AIRPHX treatment extended beyond the direct treatment space to include elevator buttons, both exterior facing the lobby and the interior of the elevators, with reductions in CFU/cm^2 ranging from 91% to 95%.

		Pre-Treatment	In-Treatment		
	Samples	6/25/2020	7/17/2020	8/7/2020	4/22/2022 (1)
AIR TESTING (CFU/M3)					
Lobby	10	433	80	140	60
Atrium Floors 2,4,6,8	4	308	100	83	67
Restaurant (halo)	6	506	33	100	78
Totals/Averages	20	430	70	117	67
Percent reduction		n/a	84%	73%	84%
Exterior Samples					
Totals/Averages	4	2,142	2,150	1,908	1,900
Percent reduction			0%	11%	11%
SURFACE TESTING (CFU/CM2)					
Lobby	7	37.0	2.9	2.8	1.8
Atrium Floors 2,4,6,8 (no separate surface tests)		n/a	n/a	n/a	n/a
Restaurant (halo)	2	21.5	1.4	1.4	0.9
Totals/Averages	9	33.6	2.6	2.5	1.6
Percent reduction			92%	93%	95%
MEMO: Elevator buttons					
Totals/Averages	2	43.0	4.0	4.0	2.0
Percent reduction			91%	91%	95%

(1) Property at full occupancy.

Table 1: *Summary of testing results - lobby.*

Conference center area

One AIRPHX PA2400 unit was placed in the meeting hallway in the conference center area of the Test Property. Since the pre-treatment testing, the unit has been moved into conference rooms with high occupancy, but it has remained deployed in the conference center area. The conference center includes several large configurable meeting rooms and several smaller meeting rooms. The testing was conducted in the meeting hallway, the large and small meeting rooms, and the fitness center located on the lower level of the Test Property at the end of the meeting hallway. The in-treatment testing on April 22, 2022 was conducted immediately after the rehearsal of a high school band in the large meeting room, and it is likely that the CFU counts for that testing date may have been elevated as a result of several hundred musicians and teachers occupying the space. A total of twenty-two (22) air samples and eight (8) surface swabs were taken (See figure 3).

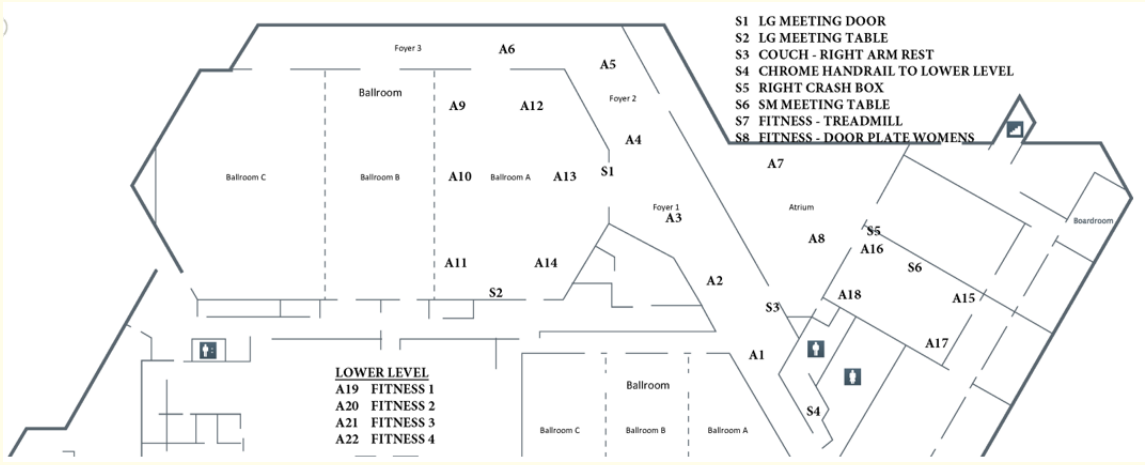

Figure 3

Pre-treatment sampling was conducted on June 20, 2020. AIRPHX units were deployed on June 25, 2020. Initial in-treatment samples were taken on July 17, 2020, representing a 22-day initial treatment period. Subsequent in-treatment testing was conducted on August 7, 2020 and April 22, 2022.

Volumetric air samples

1. Pre-treatment air samples averaged 507 CFU/m^3.

2. Initial in-treatment results averaged 71 CFU/m^3, an 86% reduction. The AIRPHX unit was operated in the meeting hallway during the initial 22 day treatment period, but the halo areas adjacent to the meeting hall, including the large and small conference rooms, experienced comparable reductions during the initial treatment period. Of special note, the fitness center, located on the lower level experienced a comparable reduction in organisms. This suggests that the oxidizing molecules distributed by the AIRPHX technology had remained effective long enough to get circulated throughout the conference center and adjacent and further removed halo spaces.

3. Additional in-treatment results including sampling on April 22, 2022 show results ranged from 17 to 250 CFU/m^3, an average of 174 CFU/m^3 and a reduction of 66% thus showing the AIRPHX system continued to be effective even with the Test Property at full occupancy. These sampling results were realized even though the large conference room and meeting hall were tested immediately after the rehearsal of a large high school band which likely increased the CFU counts.

Surface contact "swabs"

1. Pre-treatment surface swab results were 31.9 CFU/cm^2.

2. Initial in-treatment surface testing results revealed 2.3 CFU/cm^2, yielding a 93% reduction.

3. Additional in-treatment surface testing results as of April 22, 2022 revealed 1.5 CFU/cm^2, yielding a 95% reduction. It should be noted that the surface results do not appear to be impacted by the high school band rehearsal that impacted the air testing results.

		Pre-Treatment	In-Treatment		
	Samples	6/25/2020	7/17/2020	8/7/2020	4/22/2022 (1)
AIR TESTING (CFU/M3)					
Meeting Hallway	8	528	67	42	233 (2)
Large Conference Room (halo)	6	754	117	267	250 (2)
Small Conference Room (halo)	4	367	25	42	100 (2)
Exercise (lower floor halo)	4	233	58	75	17
Totals/Averages	22	507	71	109	174 (2)
Percent reduction		n/a	86%	78%	66% (2)
SURFACE TESTING (CFU/CM2)					
Meeting Hallway	2	32.5	2.2	2.1	1.3 (2)
Large Conference Room (halo)	2	36.0	2.9	3.0	2.0 (2)
Small Conference Room (halo)	2	29.3	1.7	1.6	1.1 (2)
Exercise (lower floor halo)	2	30.0	2.2	2.2	1.5
Totals/Averages	8	31.9	2.3	2.2	1.5 (2)
Percent reduction		n/a	93%	93%	95% (2)

(1) Property at full occupancy.

(2) Meeting Hallway tested immediately after a high school band practice (100+ musicians packing the spaces).

Table 2: *Summary of testing results - conference center.*

Guest rooms

In the initial 22-day treatment period, a wall mounted AIRPHX CID 75K unit was located in one of the 5th floor guest halls between rooms 522 and 524. After the first in-treatment test, the CID 75K unit was removed in order to determine if it was needed to achieve efficacy in the guest rooms. Testing was conducted in both the guest hallway and guest rooms. In the pre-treatment and initial in-treatment efforts, testing was conducted in room 524 including both air sampling and surface swabs. Because Room 524 was occupied during later in-treatment testing, subsequent testing was conducted in room 526 on August 7, 2020 and most recently in room 516. The in-treatment testing on April 22, 2022 was conducted in room 516 at the end of the hallway furthest removed from the atrium. A total of ten (10) air samples and six (6) surface swabs were taken. Six (6) air samples were taken in the hallway and four (4) air samples were taken in the guest rooms. Four (4) surface swabs were taken in each guest room including high touch surfaces like the telephone handset, the interior doorknob and the sink counter in the bathroom. The other two (2) surface swabs were taken in the hallway.

Pre-treatment sampling was conducted on June 20, 2020. AIRPHX units were deployed on June 25, 2020. Initial in-treatment sampling was taken on July 17, 2020, representing a 22-day initial treatment period. Subsequent in-treatment testing was conducted on August 7, 2020 and April 22, 2022.

Volumetric air samples

1. Pre-treatment air samples averaged 333 CFU/m^3. It should be noted that this testing was conducted during the COVID-19 pandemic when the Test Property was using its enhanced sanitation policies. Notwithstanding the additional efforts for sanitation, the CFU counts were not significantly better than the lobby or conference center.

2. Initial in-treatment results as of July 17, 2020 averaged 87 CFU/m^3, a 74% reduction. During this initial treatment period, a wall mounted CID 75K AIRPHX unit was mounted in the hallway. It should be noted that the reduction in CFU counts in room 524 exceeded the reduction in the hallway. This suggests that the oxidizing molecules distributed by the AIRPHX technology had remained effective long enough to get circulated throughout the hallway and the 5th floor guest rooms.

3. Second in-treatment testing as of August 7, 2020 was scheduled after removal of the CID 75K unit from the 5th floor hallway. The reason for removing the unit was to determine if an additional AIRPHX unit was needed to treat the guest rooms, or would the rooms receive a sufficient "halo" effect from the lobby units to effectively treat the rooms. The second in-treatment samples were in the guest hallway and room 526 and indicated an average of 70 CFU/m^3 and a reduction of 79% thus showing the units operating in the lobby were effectively treating the guest rooms on the 5th floor.

4. Third in-treatment testing was conducted on April 22, 2022 with full occupancy at the Test Property. Additional in-treatment results were conducted in room 516 at the end of the hallway, and they show an average of 53 CFU/m^3 and a reduction of 84% thus showing the AIRPHX system continued to be effective even with the Test Property at full occupancy and in the guest room furthest from the lobby atrium.

Surface contact "swabs"

1. Pre-treatment surface swab results were 26.3 CFU/cm^2. It should be noted again that these CFU counts sampled during the Test Property's enhanced sanitation protocols including additional chemicals, spraying and labor costs.

2. Initial in-treatment surface testing results revealed 1.8 CFU/cm^2, yielding a 93% reduction. This improvement was realized in the guest room itself, indicating that the sanitizing effects of the AIRPHX oxidizing molecules were realized in the guest room notwithstanding closed doors and the independent HVAC configuration of the guest rooms. Since the enhanced cleaning protocols were unchanged from the pre-treatment testing date, the improvement in guest room CFU counts can reasonably be attributable to the AIRPHX technology.

3. Additional in-treatment surface testing results as of April 22, 2022 revealed 1.2 CFU/cm^2, yielding a 96% reduction. It should be noted that the in-treatment CFU reductions in the April 22, 2002 testing can be attributed to the AIRPHX units operating in either the lobby or conference center.

		Pre-Treatment	In-Treatment		
	Samples	6/25/2020	7/17/2020	8/7/2020	4/22/2022 (1)
AIR TESTING (CFU/M3)					
Guest/5th Floor (treated with airPHX CID 75K thru 8/7)					
Hallway	6	367	106	72	50
Guest Room	4	283	58	67	58
Totals/Averages	10	333	87	70	53
Percent reduction		n/a	74%	79%	84%
SURFACE TESTING (CFU/CM2)					
Guest/5th Floor (treated with airPHX CID 75K thru 8/7)					
Hallway	2	29.0	2.1	2.0	1.1
Guest Room	4	25.0	1.7	1.7	1.2
Totals/Averages	6	26.3	1.8	1.8	1.2
Percent reduction		n/a	93%	93%	96%
(1) Property at full occupancy.					

Table 3: *Summary of testing results - guest hallway and guest room.*

Conclusion

After the initial in-treatment testing on July 17, 2020, the Test Property was being treated with three AIRPHX PA2400 units, two in the lobby and one in the conference center. The results are consistent in the lobby, conference center and guest rooms -- significant reductions in airborne and surface organisms. The test results from all spaces show lower CFU counts than both the exterior samples and the pre-treatment results, an indication of the effectiveness of the AIRPHX treatment in overcoming the existing high bioburden from the outside environment and the legacy organisms in the Test Property. The in-treatment test results showed excellent reductions in counts from both air and surface tests, indicating that the AIRPHX technology dramatically reduced the bioburden in the existing air and will significantly improve infection control efforts. Although the guest rooms did not receive direct treatment, the CFU counts were dramatically reduced. This suggests that AIRPHX technology can reduce the risk of intra-hotel infections of the type documented by Lancet Regional Health - Western. In addition, although the Test Property had enhanced sanitation protocols in effect due to the coronavirus pandemic, the AIRPHX technology resulted in more effective sanitation results while avoiding labor and chemical costs. The scalable and easily deployed nature of the AIRPHX technology appears to offer a proactive and cost-effective solution to sanitizing large and heavily trafficked facilities utilized in the hotel and hospitality industries[5].

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[5]The hotel received no complaints or comments from guests or staff concerning deployment of the AIRPHX units related to noise, odor, irritation or otherwise. In addition, despite many large gatherings and conferences hosted at the Test Property after AIRPHX units were deployed, no material instances of COVID-19 outbreaks or "super spreader" events occurred. This compared favorably to other locations managed by the global hospitality company that manages the Test Property.