

INDOOR AIR QUALITY SOLUTION FOR COMMERCIAL BUILDINGS

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SUMMARY

Poor Indoor Air Quality in commercial buildings is a growing concern these days, with several studies suggesting that indoor air pollution is 2-5 times worse than outdoor air pollution. Most individuals spend approximately 8-10 hours a day at their workplace, exposing themselves to dangerous indoor air pollutants such as bacteria, mold, viruses, carcinogenic VOC's (volatile organic compounds) generated within the office building.

Micro-organisms and VOC's are continuously released in commercial buildings and it is important to effectively keep the counts under control, since the generation of these pollutants are dynamic and cannot be predicted. It is practically not possible to sterilize the people entering commercial buildings and offices and expect them to wear sterile garments, gloves and masks used in clean room environments in the office. We also cannot avoid the use of cleaning agents, adhesives used for furniture and carpets, paints and sanitizers. This challenge sparked off the inspiration to design an innovative and effective solution that addresses the above issues and provides centralized decontamination at the source.

To effectively do this, the solution needs to integrate with the AHU to ensure that all the air circulated within the building is treated and decontaminated. In most AHU designs, the air is recirculated 10 times in one hour and since the IAQ system is integrated with the AHU, it ensures that the air is decontaminated with every pass through the system. The efficacy of the system has been tested and its performance validated in the test facility by a NABL accredited firm, and the proof of concept established practically, with field tests at live installations in fully functional office buildings.

KEYWORDS "IAQ", "Indoor pollution", "AHU", "Micro-organisms".

1 INTRODUCTION

Poor Indoor Air Quality in commercial buildings is a growing concern these days and the air cleaners available in the market are expensive and have limitations in addressing the problem at its source. They are not capable of handling large volumes of air present in commercial office buildings, most of which are air-conditioned by central plants and air handling units, cooling and delivering large volumes of air through the ducted air distribution system. The AHU is a breeding ground for mold, fungus and bacteria and with air velocities at 500 FPM, these are blown off from the cooling coil into the air-conditioned area as respirable particles causing allergies and asthma.

To conserve energy, people limit the supply of fresh air into an air-conditioned space as this will increase the cooling load. The centralized air conditioning system circulates the same air within the building and there is limited fresh air to dilute the air borne pathogens brought in by occupants of that building. Harmful VOC's (volatile organic compounds), emitted by chemical

cleaning agents, paints, varnish, and aerosols used daily in commercial buildings also contribute to poor indoor air quality.

A combination of all these factors lead to accumulation and cross contamination of pollutants in different zones within the building, affecting the quality of indoor air and leading to Sick Building Syndrome, where occupants experience headaches, fatigue and drowsiness, eye, nose, and throat irritation leading to loss of productivity and absenteeism.

The IAQ System is designed to decontaminate the surface of the cooling coil, which is the source of mold spores and bacteria forming biofilm on the coil, as well as decontaminate the air. When air passes through the UVGI and Photocatalytic reactor, all kinds of micro-organisms such as mold, bacteria, fungi, virus and dangerous carcinogenic VOC's are destroyed, thereby enhancing Indoor Air Quality resulting in increased productivity and lower absenteeism.

The system combines UVGI (ultra violet germicidal irradiation) and Photocatalytic oxidation technology in a module which aesthetically integrates with the AHU, housing all the components of the IAQ System such as UV-C emitters, Photocatalytic reactor, microprocessor controller, interconnecting cables and emitter drivers (Figure 1.)

The High Output UV-C irradiation at 254 nanometers produces germicidal rays which modify the DNA of harmful micro-organisms present (bacteria, mold spores, virus and pathogens) on the cooling coil surface as well as in the air passing through the Air handling unit, and eliminates the formation of biofilm on the cooling coil, effectively resulting in surface decontamination. When UV-C rays irradiate onto the photocatalytic reactor coated with Nano particles of titanium dioxide, hydroxyl radicals and super oxides are released, which react with the contaminants present in air and oxidize them into harmless by-products such as carbon dioxide and water vapor, thereby decontaminating the air.

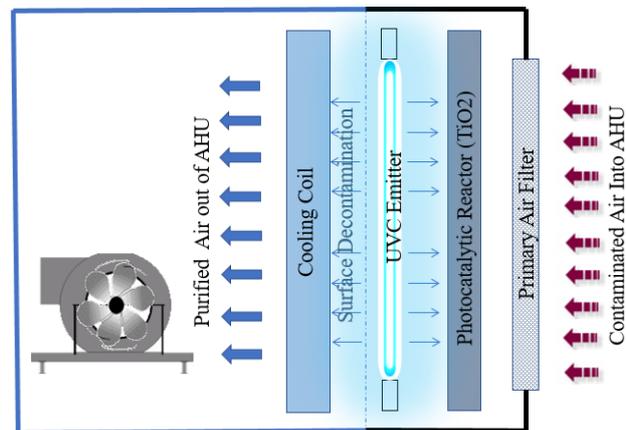


Figure 1. IAQ System Integrated with AHU Figure 2. IAQ System (schematic diagram) .

The UV-C emitters are placed at an appropriate distance between the cooling coil and photocatalytic reactor, adjusted with the help of a sliding emitter assembly, so that adequate amount of UV-C irradiation covers both the cooling coil surface, as well as the photocatalytic reactor to facilitate effective dosage of UV-C. The unique upstream design of the system ensures optimal generation of UVC at 254 nm without any deration at an operating temperature of 25° Celsius in the return air path (Figure 2.).

The Photocatalytic reactor is designed to maximize the contact of air molecules mixed with pollutants, passing through the system since this is critical for effective decontamination of air. To achieve this, the surface area of photocatalytic reactor is 30 times the face area of the cooling coil. This reduces by-pass and effective destruction of pollutants. The reactor has been specially designed to allow air to pass through with a minimal pressure drop, but prevent UVC rays from irradiating through making it safe for service personnel accessing the area as well as protects the degrading of the synthetic primary air filter.

The system has an integrated microprocessor controller which monitors critical performance parameters like UVC 254 nm intensity, emitter and ballast run hours and life. The system integrates with the BMS and interlocks with the access panel for safety of service personnel. All parameters are logged and displayed on the LCD screen of controller to monitor system functionality & diagnostics, and generate alarms in the event of failure. This data can be transferred through the inbuilt RS 485 communication port for remote monitoring to ensure that the system performs as per design.

2 METHODS

2.1 Determining the efficacy of the system for micro-organisms.

A third party NABL Certified Lab (National Accreditation Board for Testing & Calibration Laboratories) was engaged to determine the efficacy of the system. The testing facility was set up in a 2000 Sq. Ft. sterilized room with a closed-circuit air-conditioning system, with ducted supply and return air flow (Figure 3. & 4.). All openings were properly sealed to ensure that there were no leakages and no infiltration of outside air into the test area. The temperature was maintained at 24 deg. C and RH at 55 % to simulate a commercial building environment.

Two aluminium test plates, 24" X 24", one coated with Nano TiO₂ (photocatalyst) and the other without, were sterilized to establish a zero count before application of micro-organisms. A mixture containing a consortium of 5 species of micro-organisms was prepared by using 24 hours old broth culture for the bacteria, Presley sub-cultured *Candida Albicans* for Yeast, and Spore Suspension for Mold to simulate commonly prevalent airborne micro-organisms (Table 1.).



Figure 3. Testing facility



Figure 4. Closed Loop System



Figure 5. Inoculation of Micro-Organisms.

The concentrated mixture of micro-organisms was spray coated onto both treated and untreated test plates, (Figure 5.) and placed inside the AHU at 12 inches from the IAQ system. The blower was started and regulated to air velocity of 500 FPM across the coil.

Table 1. Micro-organisms and type of selective culture media.

S. No	Micro-Organisms		
	Species	Selective Culture Media	Category
1	Staphylococcus aureus	Vojel Johnson (V J) Agar	Gram Positive Bacteria
2	Escherichia coli	Eosin Methylene Blue Agar	Gram Negative Bacteria
3	Pseudomonas aeruginosa	Cetrimide agar	Gram Negative Bacteria
4	Candida albicans	Sabourauds Dextrose agar with Antibiotic	Yeast
5	Aspergillus niger		Mold

To monitor the reduction in colony forming units (CFU) of micro-organisms over a specified time interval, swab samples from the treated and untreated test plates are collected and spread over selective culture media (agar plates) to capture specific micro-organism counts and determine the kill rates for each species. (Table 1. & Figure 6.) The samples are collected at intervals of 0 hour to get the initial baseline count and further samples are collected after 15 minutes and 180 minutes. Similarly, to monitor the reduction in CFU in air, air samples are collected with an Anderson sampler as well as manual Gravimetric method, with the same selective culture media plates used above. (Figure 7.)

The air sampling was not done at 0 hour since it would take a few minutes for the micro-organisms to get airborne. Air sampling was started after 15 and 180 minutes.

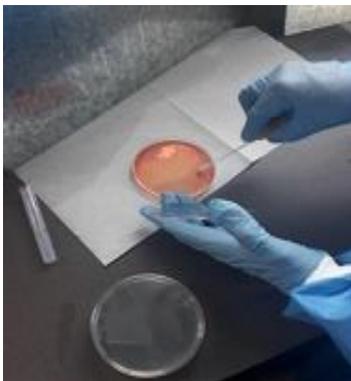


Figure 6. Swab samples on Agar Plates



Figure 7. Anderson Sampler & Selective Culture Media



Figure 8. Graywolf IAQ Sensors & Data Logger.

2.2 Determining the efficacy of the system for TVOC's.

The same test facility was fumigated, sterilized and used to determine the efficacy for TVOC's. Measured quantities of Paint thinner, Varnish, Adhesives, Cleaning Chemicals, Insect repellent, Sanitary Deodorizer & Aerosols were introduced into the air-conditioned space, to represent the commonly prevalent TVOC's present in commercial buildings. To test the efficiency of the system, TVOC counts above Toxic Limits were simulated.

Graywolf IAQ Sensors were setup for monitoring and when the reading on the TVOC sensor was stable at 31500 $\mu\text{g}/\text{m}^3$, the data logger was started to record the TVOC count and monitor TVOC reduction with the IAQ system running, in real time. Data logging was stopped when

the VOC count reached the permissible count of 500 $\mu\text{g}/\text{m}^3$. The process was repeated for the same timeframe without the IAQ system to determine the TVOC reduction count and establish the efficacy of the system (Figure 8.).

3 RESULTS

3.1 Micro-organisms.

The kill rates with the combination of the UVGI combined with the TIO₂ Photocatalyst are clearly far more efficient than UVGI alone as seen in the surface sampling test, with the reduction of CFU (colony forming units) counts reducing to 0 within the first 15 minutes of exposure. The UVGI by itself was not able to reduce the fungal count to zero for one species even after 3 hours of exposure.

The air sampling also clearly establishes that 100 % air decontamination is successfully carried out due to the efficient design of the photocatalytic reactor. The air samples collected after 15 minutes show that the micro-organisms were airborne after being blown off by the high air velocity in the AHU but after 3 hours the CFU counts reduced to 0. This substantiates the fact that there is minimal bypass due to the unique design of the reactor and that all the air circulated within the air-conditioned space is effectively decontaminated. (Refer Table 2. for details on surface and air sampling)

Table 2. Reduction of CFU in surface and air sampling tests.

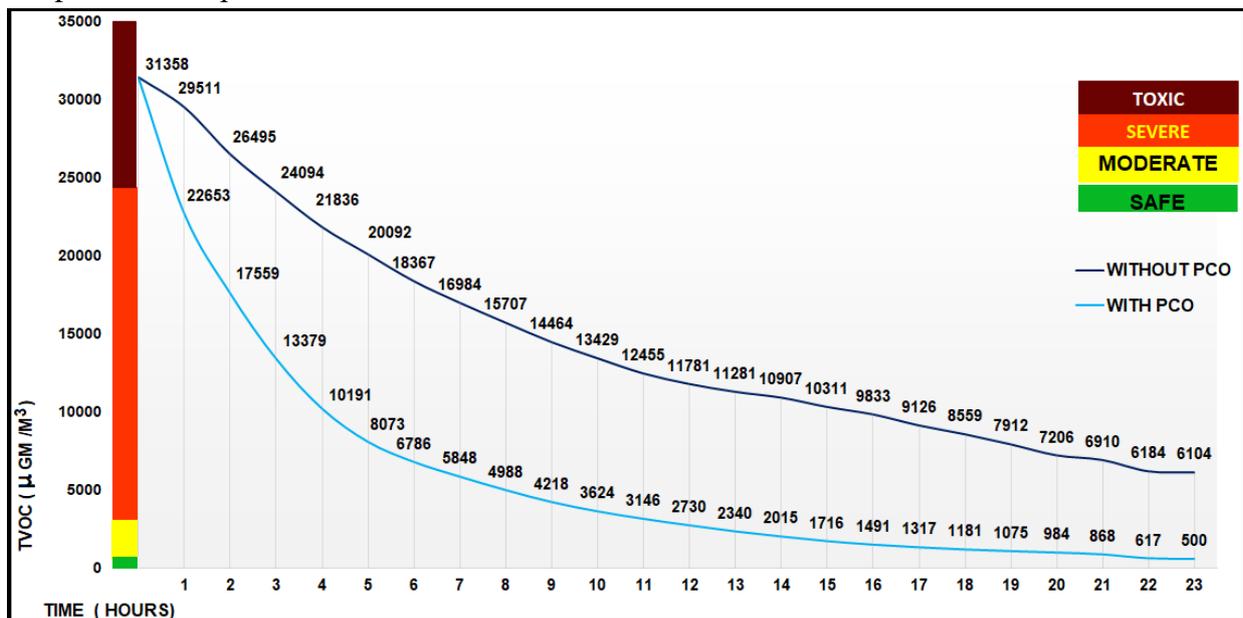
Sampling Type	Surface Sampling					Air Sampling			
	Test Plate Exposure Time					Gravimetric (Manual)		Anderson Machine	
	0 Mins	15 Mins		180 Mins		15 Mins	180 Mins	15 Mins	180 Mins
Micro-organism	Microbi al Count in CFU	Only UVGI	UVGI + PCO	Only UVGI	UVGI + PCO	At Supply Grill		At Centre of Room	
Staphylococcus aureus	>100000	21	0	0	0	0	0	NA	
E. coli	>100000	9	0	0	0	12	0	NA	
Pseudomonas aeruginosa	>100000	180	0	0	0	8	0	NA	
Candida Albicans	>100000	20	0	12	0	22	0	34	0
Aspergillus Niger	>100000	8	0	3	0	3	0	14	0

3.2 TVOC's.

The rapid decomposition rate of the TVOC's passing through the system is observed when the air is circulated in the test area with the IAQ system installed, and the TVOC count reduced from a Toxic level of 31,500 $\mu\text{g}/\text{m}^3$ to the acceptable count of 500 $\mu\text{g}/\text{m}^3$ within 23 hours. However, when the test procedure was repeated without the IAQ system, the decomposition was slow and the TVOC count reduced to 6184 $\mu\text{g}/\text{m}^3$ for the same timeframe. The combination of TVOC concentration and the exposure time to humans, is what determines the impact on health of individuals.

This test clearly establishes the efficacy of the system and proves the effectiveness of the photocatalytic reactor in rapid decomposition of VOC's. (Refer Graph 1.)

Graph 1. Decomposition of VOC's.



Practical Validation in fully functional office buildings:

The IAQ system was commercially launched and 300 + units installed in a commercial property, housing several offices and spread over 2.75 million square feet. The units were installed on AHU's with varying sizes and capacities ranging from 12,000 to 24,000 CFM. A pre-installation microbial analysis was done on the coils of 5 AHU's selected by the client. Swab samples were collected from the cooling coils before installing the IAQ system and spread over culture media to establish the micro-organism counts in CFU's. This test was repeated 30 days post installation along with Anderson Air Sampling in the occupied air-conditioned area, and the results clearly show the effective reduction of micro-organisms. The TVOC analysis was also done post installation of the IAQ system and the results show that the TVOC counts are being controlled by the system effectively. (Refer Table 3.) Post installation of the IAQ system, these offices comply with the IGBC (Indian Green Building Council) Healthy Building Standard and qualify as Class A/B on these IAQ parameters.

Table 3. Microbial & TVOC analysis Pre- & Post installation of IAQ System.

Benchmark with IGBC – Healthy Building Standards for Micro-organism and TVOC control.								
Customer	Microbial Count (CFU) Sample Surface Area 25 Sq. cm ²			Microbial Count (CFU/m ³) Air Sampling		TVOC (µg/m ³)		
	Pre- Installation Oct 2017	Post Installation Dec 2017	Post Installation Mar 2018	Post Installation Mar 2018	IGBC Class	Post Installation Dec 2017	Post Installation Mar 2018	IGBC Class
Customer 1	1000++	0	8	77	B	60	122	A
Customer 2	1000++	1	20	48	A	357	157	A
Customer 3	1000++	56	4	34	A	75	125	A
Customer 4	1000++	55	4	28	A	89	147	A
Customer 5	1000++	2	10	127	B	201	140	A

IGBC “Healthy Building “Standard , Threshold values for Microbial Count & VOC: 50 CFU/m³ & 500 µg/m³ for “ Class A “ 150 CFU/m³ & 650 µg/m³ for “ Class B” respectively .

CONCLUSIONS

Micro-organisms and VOC’s are continuously released in commercial buildings and it is important to effectively keep the counts under control since the generation of these pollutants are dynamic and cannot be predicted. It is practically not possible to sterilize the people entering commercial buildings and offices and expect them to wear sterile garments, gloves and masks used in clean room environments in the office. We also cannot avoid the use of cleaning agents, adhesives used for furniture and carpets, paints and sanitizers. In most AHU designs, the air is recirculated 10 times in one hour and since the IAQ system is integrated with the AHU, it ensures that the air is decontaminated with every pass through the system.

The IAQ system is an ideal solution to address the growing concern of poor indoor air quality, and can be easily integrated with AHU’s in new projects as well as retro-fitted in existing offices which makes it an effective and viable solution to improve Indoor Air Quality on a sustainable basis. The IAQ system has been evaluated and certified as a Green Product by the CII – Green Products and Services Council at the International Green Building Congress in Jaipur, India in October 2017.

ACKNOWLEDGEMENTS

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