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Application of Photocatalysis to Reduce VOCs in Indoor Air

Volatile Organic Compounds (VOCs) are a classification of Indoor Air Quality (IAQ) contaminants that affect the productivity of workers, school children, and the population who spend a majority of their active lives in buildings. The Healthy Buildings Institute (Fairfax, VA, USA) had found that formaldehyde and VOCs were at inappropriate levels in 5% and 3%, respectively, of the 2,500 buildings included in their extensive research. Inadequate, or no ventilation was found to be a common cause of contaminant accumulation (42% of the surveyed buildings).

ANSI/ASHRAE Standard 62-2001, "Ventilation for Acceptable Indoor Air Quality", specifies minimum ventilation rates and indoor air quality (IAQ) acceptable to humans in occupied areas, i.e., buildings. Its intentions are for designers of HVAC systems to minimize the potential for adverse health effects in occupied spaces through the use of outside air dilution.

This document stipulates that "acceptable" outdoor air meets the National Primary Ambient-Air Quality Standards for Outdoor Air as set by the US EPA. The contaminants listed in the standard do not include VOCs. They further state that if the measured contaminant levels exceed the respective limits for "acceptable" air, then the use of air cleaning systems is recommended.

VOCs are different from US EPA contaminants such as SO₂, since they originate mostly from inside of a building. Common emitters of VOCs include; carpet, wall, and furniture; pest control agents; paints and varnishes; fax, printer, and copier machines; humans; and mold/mildew growth.

The Indoor Air Quality Association (IAQA) of Virginia, USA has summarized a listing of guidelines for indoor environments. Table 1 summarizes parameters relating to VOCs.

Table 1
IAQA VOC Proposed Guidelines

Parameter	Limit / Range	Reference
VOCs	3.00 mg/m ³ (0.64 ppm)	Molhave, 1990
Formaldehyde	0.06 mg/m ³ (0.05 ppm)	Health and Welfare, Canada

Cleaning systems for VOCs typically involve the use of phase transfer, i.e., transfer from the gaseous phase to a solid phase, i.e., media. Examples of phase transfer media include; activated carbon or potassium permanganate-impregnated zeolites, or their combination for molecular

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adsorption. ASHRAE or HEPA filters are not designed for the very small molecular sizes of VOCs.

Some issues to contend with when using phase transfer media to remove organics include;

- ◆ the type of organic to be removed (lower molecular weight compounds such as formaldehyde and acetone are more difficult to remove),
- ◆ the concentrations where ppb concentrations are less attainable than higher ppm levels which may exceed regulatory standards (OSHA limit for formaldehyde is 0.75 ppm)
- ◆ the media replacement (quarterly to annually), and
- ◆ its final handling and disposal (may be hazardous waste?).

Further, activated carbon acts as a food source and growth support, thus possibly increasing the accumulation of bacteria and fungi.

Photocatalytic Oxidation (PCO) is an emerging technology that provides chemical-free oxidation of VOCs and microbes along with re-generating capability to preclude the issues associated with media replacement and disposal. This process involves the activation of a catalytic surface with light, most efficiently with UV lamps having a spectra less than 390 nanometers (nm).

Many researchers and national governments have studied PCO to determine its practicality in use in various applications that range from remediating hazardous waste sites to simply improving Indoor Air Quality in commercial office buildings.

Table 2 contains an abbreviated list of studies and possible applications.

For air applications, PCO technology is best applied using titanium dioxide-coated supports, i.e., non-organic filter cloth, wire or ceramic mesh, transparent beads, etc. The high surface areas offered by the catalyst need to be illuminated with UV light of at least 3 milli Watts/cm² for effective VOC conversion. Residence times for single pass applications are to be on the order of 0.5 or greater seconds. For optimum oxidation of VOCs, the relative humidity should be between 20 and 60%, since minimum moisture levels are needed for the reaction to initiate, while too much moisture will compete with catalyst sites.

Photons from UV light constantly bombard the photocatalyst to generate an electron transfer on the surface to release both electrons and their positively-charged counterparts, “holes”. Holes react with oxygen and water (moisture from humidity) to form the hydroxyl radical, one of the strongest oxidizing species. Other oxidizers form, including hydrogen peroxide. When VOCs pass through a PCO assembly, the organic compound adsorbs to a catalyst site that contains the hydroxyl radicals and other oxidizers, react on the surface, convert to carbon dioxide and water, then desorb from the catalyst, leaving the site open for the next VOC.

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The technologies supporting PCO have allowed it to be more cost comparable to phase transfer media for IAQ applications. Examples include; nano-sized catalyst particles, more powerful/efficient UV lamps and ballasts, better understanding of reaction kinetics of known IAQ contaminants, and the ability to design and support a PCO apparatus in the ventilation ductwork.

Benefits to using PCO technology is its ability to inactivate microorganisms and decompose ozone at the same time as removing VOCs, further enhancing the value of the technology in improving IAQ.

Table 2
PCO Applications

Application	Objective/Result	Reference
Removal of trichloroethylene (TCE) from Contaminated Aquifers	Site provided up to 90% TCE conversion in a single pass.	US EPA Report No. SR-98/504, March 1999
Removal of Ethylene from Air in Produce Sections	Remove a naturally occurring hormone that causes premature ripening/aging of fruits, vegetables, and plants.	University of Wisconsin/KES
Reduction of Low-Level VOCs associated with Indoor Air Quality	Removed sub-ppm levels of acetone and formaldehyde in several pilot units.	“Photocatalytic Oxidation of Organic Pollutants Associated with Indoor Air Quality”, University of Colorado, Denver and National Renewable Energy Laboratory, June 1998
Reduction of VOCs in Indoor Air Quality	Removed ppm levels of multiple compounds, including nicotine-related chemicals in a pilot unit.	“Heterogeneous Photocatalysis for Control of Volatile Organic Compounds in Indoor Air”, National Renewable Energy Laboratory, September 1996
Removal of Acetone Vapors	Removed ppm levels of acetone in a pilot reactor.	Widener University and Catalyx technologies, LLC

Feel free to contact Catalyx directly for more information.

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