Methods of Air Cleansing – Filtration, Adsorption, Ionization and Free Radical

Overview

There are only so many ways that you can “clean” air of particles and volatile organic chemicals (VOC), bacteria, virus and mold. In general these include:

- Filtration
- Adsorption
- Ionization to generate charged particles
- Photolysis to generate free radicals

Removing particles from air requires the use of high performance filters, which are aided by ionization which creates positive and negative charged particles which can be attracted to charged collection plates or clump together to fall as “dust”. If sufficient energy is generated, you may also create positively and negatively charged VOC’s. The charged organic compounds can undergo some degree of decomposition, although the oxidation by-products themselves can be as much of a health issue as the original VOC. There is very little real data to show how extensive the decomposition process is with many of these systems.

Removing VOC’s and microorganisms can be done in a variety of ways. You can absorb small quantities, in the low parts-per-billion (ppb) range, onto a filtration medium, like activated charcoal which will trap them. You can also adsorb small quantities, in the low ppb range on certain catalytic surfaces. These catalytic surfaces can then be irradiated with selected wavelengths of UV energy to generate reactive oxygen species which decompose the adsorbed material.

The most efficient method to eliminate high ppb and low parts-per-million (ppm) levels of VOC’s and pathogens continuously present in air (and on surfaces) requires the use of high performance vapor phase oxidative air cleansing systems that generate hydroxyl radicals – the process used in nature. Hydroxyl radicals react one million times faster than the next most powerful oxidant, ozone. HGI systems have confirmed that their Odorox® products produce concentrations of hydroxyls equivalent to those produced in nature and react effectively with high ppb levels of VOC’s (confirmed by independent third party testing).

Other manufacturer’s electric discharge or ionization cleaners (like “Plasma Ionizers”) make claims that they produce hydroxyl radicals in concentrations similar to HGI’s photolysis method but they offer no data. Ionization devices generate positively and negatively charges particles, not free radicals so that their reactions with VOC’s are very different than those for Odorox® systems or those found in nature. There is no evidence that they produce hydroxyl radicals. The ionization process involves electric discharge and is modeled on the Siemens ozonizer patent. It will innately produce considerable amounts of ozone.

The only method to be proven safe both in nature and in an independent clinical/toxicological testing laboratory is HGI's Odorox® multiple UV energy method. The FDA will only recognize safety data associated with a particular type of device. All vendors must produce their own efficacy and safety data.

High Efficiency Particulate Arrestor/Air (HEPA) Filtration

A HEPA filter is a mechanical filter that traps airborne particles as they pass through an air filter. A true HEPA filter is rated to remove 99.97% or greater, of all particles that are 0.3 microns in size or larger (1 micron is 10^{-6} meter.). As a reference point a human hair is approximately 60 microns in diameter and a grain of pollen is 5 microns. 90% of all airborne particles are less than 10 microns in size and the challenge with air purifiers is that most of these particles are too small to see. The light weight and low mass of these particles allow them to be suspended in the air for extended periods of time while the larger and heavier dust type particles tend to settle on the ground much more quickly. HEPA filters are effective for 0.3 microns or greater concentrations of particulates and have to be replaced as they become saturated and can become an emission source.

Electronic Air Cleaners

An electronic air cleaner uses an electrical charge to remove particles from the air. The most common type is also known as an electrostatic precipitator and has a series of plates that the air is passed through. The first set of plates in the electronic air cleaner are negatively charged and that negative charge is passed onto the airborne particles that are moving through the electronic air cleaner. The second set of plates is positively charged so the airborne particles that received a negative charge are attracted to the positive plates.

The key advantages of electronic air cleaners are that they do not use a permanent type filter so there are no filter replacements. Since there are no filters, there are no restrictions on air flow.

These types of devices generate ozone, which may accumulate to unsafe levels. Some electronic air cleaners have received poor third party reviews due to high levels of ozone that is produced during operation of the air cleaner. The Occupation Safety and Health Administration (OSHA) has established 0.1 ppm (parts per million) for an eight hours exposure, as the maximum level at which a device is deemed to produce safe levels of ozone. Furthermore, in 2010 the California Air Resources Board has established ozone criteria for air cleaners to be sold in the state of California. Electronic air cleaners that do not meet this criterion are not authorized for sale to California residents.

Electrostatic Precipitation

The patent for an electronic air cleaner type device that uses electrostatic charges was applied for in 1907 by Dr. Frederick Cottrell. The ionic air purifier is also referred to as an ion generator and is basically half of an electrostatic precipitator. This means that as the particles enter the air purifier they receive an electrical charge but unlike the "Electronic Air Cleaner" there is no set of plates with an opposite charge in the ionic air purifier to capture the particles. The implication of this is that the charged particles will then adhere to the walls, carpeting, clothing, or any surface they can stick to. If you are looking for allergy or asthma relief, then an ionic air purifier is probably not a good choice unless the air purifier also uses an effective filtration method such as HEPA air filters to capture the charged particles.

Most air ionizers generate negatively charged particles. If the energy is high enough, they generate negatively charged molecules from volatile organic compounds.

Non-Thermal Plasma Generators (NTP)

NTP are a special class of air ionizers based on the Siemens ozonizer. "By means of electrical discharge between two electrodes (they) generate a non-thermal plasma (NTP) consisting of electrons of particles of high energy (3-6 eV) corresponding to 290-580kJ/mol which are supposed to react with air pollutants to form toxicologically harmless products". [Heberer, et. Al., "Uberlegungen sur Wiorkung und Toxickologishchen Relevanz von NTP-Reinigungsgaraten. Gefahrstoffe – Reinahlt. Luft 65, (2005) no. 10, p. 419-424]. The principals of the NTP barrier discharge reactors have been described in detail by Chirokov et al. ("Atmospheric pressure plasma of dielectric barrier discharges, Pure Appl Cehm. 77, (2005) pp 487-495.)

The electrons produced are of high enough energy to generate atomic oxygen, which reacts with oxygen to produce ozone, although, not as much as commercial ozone generators. These systems do not produce hydroxyl radicals directly but may do so indirectly by the reaction of atomic oxygen with water and to a small degree by the reaction of ozone with alkenes generally present in ambient VOC's at about 20 ppb. Also produced as by-products in unknown amounts would be superoxides, hydroperoxyl radicals, hydrocarbon peroxyl radicals etc.

VOC's can react directly with the electrons in the plasma, generating a cascade of radical anions. These go on to react with reactive oxygen species (ROS) and other VOC's to generate a complex mixture of oxidized organic by-products. This mixture is not the same mixture that would result naturally from the sun's UV radiation interacting with oxygen and water in the atmosphere.

Photocatalytic Oxidation (PCO) Air Cleaners

Photocatalytic oxidation (PCO) systems generate ROS by irradiating a semiconductor catalyst coated surface with UV energy in the range of 254-385 nm. This is energetic enough to activate the catalyst surface but not energetic enough to directly produce ozone. Typically titanium dioxide (TiO_2) is used as the catalyst, but there can be multiple catalysts in the coating. The systems are designed so that VOC's, bacteria, mold etc. are adsorbed onto the catalyst surface. When the catalyst surface is irradiated with UV light, various reactive oxygen species are produced. It is presumed that superoxide and hydroxyl radicals are among these species, although no measurements have been reported to confirm this. The oxidative species react with the adsorbed materials and decompose them. "Photo hydroionization" is a trade name for a PCO system that uses a 4-part catalyst. PCO systems were designed for the treatment of limited spaces; the first implementations were on the space shuttle.

PCO systems have been reported to have significant limitations with regard to remediation [1, 2].

- System oxidative capacity is limited by catalyst surface area
- Systems have proven to work best at low air speeds confirming that reactions are occurring predominantly on the catalyst surface. High speeds are 340 cfm and low speeds would be half to one third of that rate – or lower. This limits their use treating large areas.
- Humidity inhibits the rate of reaction as water competes for catalyst active sites
- Catalysts are subject to deactivation due to inorganic contamination
- Oxidation is incomplete, producing an effluent that has 3.4 to 4.6 times more formaldehyde and acetaldehyde. Mathematical modeling studies indicate that there would continue to be a three- fold increase in the steady state concentrations of these (and other) incomplete oxidation products given the flow rates and capacity of this technology[3].
- Decomposition issues of TiO_2 caused by the oxidative decomposition of the binder with subsequent release of TiO_2 particles[5].

Multiple Wavelength UV Irradiation Air Cleaners

Odorox® systems use multiple wavelength UV to irradiate oxygen and water vapor directly to generate hydroxyl radicals and other ROS. HGI has independently verified that their systems produce concentrations of hydroxyl radicals equivalent to the abundant levels produced in nature[4]. HGI systems use multiple wavelength UV to destroy ozone so that it does not accumulate under normal use conditions.

The Odorox® oxidative process is very efficient as evidenced by the ability to decompose both the original VOC's and their oxidation by-products as measured by tracking formaldehyde concentrations. Formaldehyde is the smallest VOC decomposition product. When VOC oxidation is incomplete, formaldehyde builds up.

HGI independent third party test results for Odorox® systems indicate that formaldehyde levels do not accumulate during use. They rapidly reach a very low, steady state level of less than 15 ppb, well below FDA and OSHA compliance levels and nearly at the baseline of environmental levels. Other vendors claim that they use UV irradiation to generate hydroxyl free radicals, but they have not provided data to support the amounts that they produce nor the amounts and safety of their by-products.

1. Bill Jacoby, "Photocatalytic Oxidation", Penn State University, College of Engineering, 2000.
2. A.T. Hodgson, D. P. Sullivan and W. J Fisk, "Evaluation of Ultravolatile Photocatalytic Oxidation for Indoor Air Applications", Lawrence Berkeley National Laboratory, #58936, 2008.
3. Jim Rosenthal, "Study on Photocatalytic Oxidation Raises Questions About Formaldehyde as a Byproduct in Indoor Air", Lawrence Berkeley National Laboratory, memo dated 12-18-08
4. HGI joint study with Lovelace Respiratory Research Institute, 2011.
5. Rabek, J.F. Polymer Photodegraduation: Mechanism and Experimental Methods, Chapman & Hall (Pub.), 1st Ed., 1985.