HGI's Odorox® System Efficacy, Chemistry and Safety

Introduction

It has been known since the 1970's that atmospheric hydroxyl radicals (hydroxyls) are continuously produced by the action of the sun's radiated ultra violet light (UV) on oxygen and water vapor in our atmosphere. It was only recently that researchers determined that the hydroxyl concentration during the day was between 500,000 to 2.6 million hydroxyls in each cubic centimeter of ambient outdoor air. Hydroxyls are the main driving force behind the daytime reactions with hydrocarbons in the troposphere and decompose most natural and man-made pollutants including greenhouse gases like methane and ozone. Atmospheric hydroxyls are also proven to kill bacteria, virus, and mold because they are able to penetrate their permeable cell membranes. Atmospheric hydroxyls are a critical component of nature's dynamic ability to provide environments that are free of pathogens and harmful chemicals. [1, 2]

As our indoor environments have become increasingly closed off from the outdoors, we have come to depend on ventilation systems to maintain safe indoor air. Outdoor hydroxyls are very short-lived, however, and do not survive long enough to cleanse indoor air. Increasingly our homes, work places, indoor recreational and travel environments have chronic, unhealthy levels of Volatile Organic Compounds (VOC's) and pathogens. Indoor air sanitizing systems were developed to address these contaminants.

Efficacy

Historically, ozone generators were the first indoor sanitizing devices. Ozone is effective, but it reacts so slowly that high concentrations in the parts-per-million (ppm) range are needed to be effective. At these levels, ozone is toxic to humans and animals and damaging to materials.

When atmospheric hydroxyls were discovered to be nature's principal sanitizing agent , universities, government laboratories and corporations did much research on their chemistry in nature.[1,2,3,4] Atmospheric hydroxyl radicals are a superior sanitizing agent as they are significantly more reactive than ozone – on the order of a million times more reactive. They effectively kill bacteria, virus and mold on both solid and porous materials and decompose a broader range of VOC's and inorganic gases than any other oxidant – even ozone – without damaging fabrics, latex, leather, rubber, plastic, vinyl, metal and other materials. Because atmospheric hydroxyls are so reactive, they do not linger in the indoor environment. These desirable properties have resulted in a number of commercial devices trying to produce atmospheric hydroxyl radicals to safely re-establish the natural cleansing cycle indoors. The efficacy of these systems has been demonstrated by empirical, chemical and bacteriological data broadly published by academic and commercial entities and verified by HGI internal studies.[1,2,3,4,5]

Chemistry

There are two basic approaches to generating hydroxyls: the photocatalytic method and the use of multiple wavelength UV. The photocatalytic method radiates UV energy on a surface coated with a semiconducting catalyst like titanium dioxide. This promotes the formation of hydroxyl radicals and superoxide radicals near the catalyst surface where they then react with adsorbed VOC's. The method uses a long wavelength of UV energy so that little to no ozone is formed. Developed for the space shuttle, the approach generates sufficient oxidants to treat small volumes of air with low concentrations of VOC's, but is ineffective in larger volumes of air or with higher concentrations of VOC's. In these applications, the oxidant levels produced are too low to efficiently oxidize the VOC's and the resulting oxidized organic by-products. The result is a buildup of by-products, particularly formaldehyde. Researchers at the Lawrence Berkeley Research Laboratories have reported that the method intrinsically results in formaldehyde levels that are 3-4 times higher than background levels.[3, 4]

The Odorox® method utilizes multiple wavelength UV. These powerful wavelengths of UV energy are produced so that far more effective concentrations of free hydroxyl radicals are generated directly within the reaction chamber. This enables oxidation of VOC's and pathogens with concentrations of reactive oxygen species which can be propagated throughout the treatment space, all of which contribute to air cleansing. HGI commissioned studies at the Lovelace Respiratory Research Institute (LRRI) to independently measure the rate of hydroxyl radical formation by an Odorox® Boss™ system. They verified that the levels of hydroxyls produced were similar to those found in nature and that they reacted with airborne VOC's and other gases like nitric oxide, formaldehyde and ozone. Measured reaction rates are incredibly fast, on the order of 20-50 milliseconds. These studies have been further analyzed and interpreted by a leading industry expert in atmospheric hydroxyl radical chemistry, Dr. David Crosley.[5]

Airborne hydroxyls are the perfect sanitizing agent. They react with a broader range of chemicals and are over one million times faster than ozone, bleach or other sanitizing agents. They react principally by removing a hydrogen atom and forming an organic radical that is subsequently decomposed by continued oxidation. The organic radicals formed set up a complex chain reaction of many radical by-products. These by-products include secondary oxidants like peroxy and oxy radicals that are themselves good sanitizing and deodorizing agents as they are more stable than the original hydroxyl radical and able to penetrate large volumes of air. As in nature, the individual steps grow exponentially in complexity. The net result is that organic compounds are reduced in size and oxidized until they eventually form carbon dioxide, oxygen and water. As long as the system is running, the chain reactions persist.

As in nature, ozone is necessarily produced as a by-product of the UV irradiation process in air. Once formed it is decomposed by a variety of pathways including UV energy decomposition, reaction with VOC's and reaction with hydroxyls. Although hydroxyls will react with most VOC's before ozone can, ozone is an important part of the air cleaning process because of its ability to react with a special type of VOC, a carbon-carbon double bond - called an alkene - to generate hydroxyl radicals throughout the treatment space. Alkenes are produced in nature by general chemical reactions and by plants, animals and humans – which respire parts-per-billion (ppb) levels of an alkene called isoprene. Indoors, alkenes are generated by the out gassing of fabricated wood products, fabric, solvents, cleaning products (such as Pine-Sol®, a pinene/terpene alcohol based cleaner) etc. and steady state levels in the ppb range are common. When ozone reacts with alkenes they produce hydroxyl radicals that treat the air and surfaces far removed from the site of hydroxyl generation.

Safety

As a category, the FDA does not regulate or require premarket 510(k) approval for UV irradiation air cleaning devices since they irradiate ambient air and sanitize in a manner similar to that found in nature. The FDA and other regulatory agencies do monitor ozone and the smallest decomposition products from these devices - acetaldehyde and formaldehyde – as an indication of safety.

Acetaldehyde and formaldehyde build up as larger VOC's are decomposed by hydroxyls. They are the last products produced before complete oxidation to carbon dioxide and water. A device that produces sufficient concentrations of hydroxyl radicals will keep the steady state levels of these terminal oxidation products near background levels as these small VOC's react with hydroxyl radicals more rapidly than larger VOC's. This is what happens in nature. Studies at LRRI and Columbia Analytical Laboratories (Sunnyvale, CA) confirmed that HGI systems produce sufficiently high concentrations of hydroxyls to efficiently decompose ambient VOC's and their by-products so that formaldehyde and acetaldehyde rapidly reached low steady state levels that remained near ambient baseline levels of 10-15 ppb for extended periods.

OSHA requires that indoor ozone levels are below 100 ppb for safe, long-exposure. Typical natural ozone levels range from 20-60 ppb. HGI technology maintains these same natural levels through the use of customized optics, system design optimization, recommended ventilation practices and machine selection for given volumes of treated air. For its larger industrial systems, HGI has integrated real-time interactive process controls so that oxidant levels can be accessed remotely and measured continuously, enabling machine settings to be adjusted automatically to maintain whatever oxidant levels that are required.

Toxicology

Researchers such as Weschler and Shields have speculated on the potential health hazards of the oxidation products resulting from use of UV hydroxyl radical air sanitization devices indoors.[6]
At HGI's request, the National Institute of Environmental Health Sciences searched the NIH files, PubMed and the National Library of Medicine and "cannot find any hard science or research indicating that hydroxyl radical generation is harmful to human health. That applies to both atmospheric and man-made generation" (Colleen Chandler, NIEHS Office of Communications and Public Liaison, 08-05-2010). Further, at HGI's request, the CDC, FDA, OSHA and NIH researched their databases and did not find any data indicating that hydroxyls were unsafe. None of these agencies indicated that their approval was required for commercial use. It is not likely that this will change as hydroxyl radical sanitizing systems generate levels of these by-products that match those produced by the sun outdoors.

Although no adverse effect from the use of UV hydroxyl generators have ever been reported, there have been no toxicology studies to verify this. Therefore HGI conducted a comprehensive Good Laboratory Practices (GLP) Toxicity Study with an industry leading clinical contract research company, Comparative Biosciences, Inc. This study involved the use of forty (40) test rats and twenty (20) control rats and was conducted in compliance with the US Food and Drug Administration's Good Laboratory Practices regulations (21 CFR Part 58). Extensive data was collected including behavioral, physiological, neurological, hematology, clinical chemical analysis, neurology, ophthalmology, and gross histopathology. The study results indicated that the test animals tolerated the exposure well with no abnormal clinical observations. There were no histopathology/cytopothology (cellular level) differences between the control rats and the exposed rats. During analysis, specific attention was paid to the skin, eyes, nasal turbinates, larynx/pharynx, and respiratory system. There were no changes in these organs and they appeared to be within normal limits in both the control and treated animals. Interestingly, it was noted that treated animals appeared to be more alert and social during the day-light hours than untreated animals. These results are applicable only to HGI Odorox® systems, which use UV light of a particular bandwidth of wavelengths and custom optics in certain configurations. Other systems that use different optics, catalysts, or incorporate other methods such as adding different oxidizing agents or organic chemicals would need to be separately evaluated as the resulting mixture of by-products would be "unnatural" and could pose health problems.

In conclusion, HGI air/surface sanitizing systems have been proven to match the sun's power in generating safe levels of hydroxyl radicals and secondary oxidants, including non-accumulating ozone, which together, effectively sanitize small and large indoor spaces.

HGI Industries, Inc.
Scientific Advisory Board Publication

Dr. Connie Araps, Chairman

1. D. E. Heard, "Analytical Techniques for Atmospheric Measurement", Blackwell Publishing, 2006 – professor at the University of Leeds, UK) and references cited therein.
2. R. Atkinson, "Kinetics and Mechanisms of the Gas-Phase Reactions of the Hydroxyl radials with Organic Compounds", Journal of Physical and Chemical Reference Data, Monograph No.1, 1989.
3. J. Rosenthal, "Study of Photocatalytic Oxidation Raises Questions About Formaldehyde as a Byproduct in Indoor Air", Lawrence Berkeley National Laboratory, December 19, 2008.
4. A. T. Hodgson, D. P. Sullivan and W. J. Fisk, "Evaluation of Ultraviolet Photocatalytic Oxidation for Indoor Air Applications - Conversion of Volatile Organic Compounds at Low PPB Concentrations", LBNL-58936, 2008.
5. HGI Scientific Advisory Board Report, Dr. C. Araps, Chairman, July 2011.
6. C. Weschler and H. Shields, Environmental Science and Technology, "Production of the Hydroxyl Radical in Indoor Air", Vol. 30, No. 11, 3250-3258, 1196 and references cited therein.

