# HGI's Odorox® System Efficacy, Chemistry and Safety

## Introduction

It is well established that the hydroxyl radical (HO) is present throughout the troposphere due to the sun's ultraviolet energy reacting with ambient gases.[1,2] During a sunny day typical concentrations are 2-3 million hydroxyls in each cubic centimeter of ambient outdoor air.[1,2,3] Hydroxyls are the main driving force behind the daytime decomposition of volatile organic compounds (VOC) and inorganic gases.[3,4] Hydroxyls decompose most natural and man-made pollutants including methane, ammonia, ozone, NO, CO – among others - and a broad range of aliphatic and aromatic hydrocarbons.[7] Atmospheric hydroxyls are also proven to kill bacteria, virus, and mold because they are able to react with and decompose the chemicals that constitute the cell membranes. Atmospheric hydroxyls are a critical component of nature's dynamic ability to maintain outdoor environments that have low steady state levels of pathogens and harmful chemicals that we have evolved to tolerate.

Industrialization has increased the output of toxic chemicals that pollute both outdoor and indoor environments; often beyond safe levels. While the sun's action minimizes outdoor pollutants, our indoor environments increasingly have chronic, unhealthy levels of VOCs and pathogens; as much as 3 to 5 times higher than those outdoors in spite of ventilation. Outdoor hydroxyls are very short-lived, and do not survive long enough to cleanse indoor air. Odorox® indoor air sanitizing systems were developed to minimize indoor pollution and restore nature's safe balance.

## Efficacy

Atmospheric hydroxyl radicals are the most effective vapor phase sanitizing agent because they react extremely rapidly with the broadest range of chemicals and microorganisms. This is due to their high electrochemical potential and the nature of their free radical chemistry. Hydroxyls react by abstracting hydrogen atoms from nearly all aliphatic organic chemicals and by addition reactions to aromatic organic chemicals.[7] This unique chemistry enables Odorox® systems to rapidly decompose most industrial chemicals including benzene, toluene, xylene, and styrene – among others – that are difficult to decompose by other oxidative methods. Odorox® systems also effectively kill bacteria, virus and mold in air and on solid and porous materials by reacting with the lipids, proteins and carbohydrates that constitute the microorganism's cell walls. Because atmospheric hydroxyls are so reactive, they do not linger in the indoor environment. The efficacy and safety of the Odorox® hydroxyl purifying systems has been validated by extensive third-party chemical, engineering, microbiological and toxicology data and, for a selected model, by the FDA (Odorox® MDU/Rx™ 510k #133800).

  

## Chemistry

In the troposphere, the major mode of formation of hydroxyls is by the photolysis of ozone by UV radiation longer than ~315 nm, since shorter UV wavelengths are filtered out by the stratospheric ozone layer. This results in the formation of an energetic form of singlet oxygen (O), some of which reacts with $H_20$ to form two OH radicals. Odorox® systems generate hydroxyls by a different pathway which uses shorter wavelength UV radiation to cause the direct scission of $H_20$ to form two OH radicals. Hydroxyls react too quickly to be measured under normal laboratory conditions using conventional analytical methods, so HGI commissioned studies at the Lovelace Respiratory Research Institute (LRRI) to independently measure the rate of hydroxyl radical formation and reaction with a representative VOC by an Odorox® Boss™ system in an ultra-clean environmental chamber. They verified that the levels of hydroxyls produced were similar to those found in nature (3 million OH per cubic centimeter) and that measured reaction rates were incredibly fast, on the order of 20-50 milliseconds.[5] These studies have been further analyzed and validated by a leading industry expert in atmospheric hydroxyl radical chemistry, Dr. David Crosley, and were published by the Journal of the Air and Waste Management Association.[8]

Atmospheric 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. The fastest reaction path involves the abstraction of a hydrogen atom (H) and formation of an organic radical that is subsequently decomposed by continued oxidation. For aromatic chemicals like benzene and its derivatives that do not have an easily abstracted H, the first step is addition of OH to the double bonded ring structure, resulting in ring opening.[7] Once the aromatic ring is opened, decomposition proceeds in the same way as open chain aliphatic compounds. The initial organic radicals formed (C·) react rapidly with oxygen initiating a complex radical decomposition process where terminal carbons are lost as $CO_2$. By-products include secondary oxidants like peroxy and oxy radicals (C-O-O· and C-O·) 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 and the intermediate oxidation by-products remain at low parts-per-billion (ppb) steady state levels similar to those found outdoors.

As in nature, ozone is produced as part 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 VOCs 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 that contains 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 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 and other governmental agencies do not regulate or require pre-market approval for shielded UV air and surface cleaning devices used in residential and commercial applications as they irradiate ambient air and sanitize in a manner similar to that found in nature. The FDA does require 510(k) premarket approval of UV sanitizing systems for use in medical facilities. The FDA reviewed a broad range of engineering, analytical, chemical, microbiological and toxicology data for the Odorox® MDU/Rx™ system and approved its use in occupied spaces in medical facilities (510(k) #133800). The FDA does not regulate UV sanitizing systems that are integrated with heating and ventilation systems in commercial or medical facilities, such as the Odorox® Induct™ and MVP14™, MVP24™and MVP48™ systems. These have the capacity to safely treat millions of cubic feet and reduce even high parts-per-million (ppm) levels of chemicals to low ppb levels to meet regulatory safety requirements. This has been demonstrated by HGI in many industrial and commercial applications.

Regulatory agencies such as OSHA do monitor the chemicals that can be generated from UV sanitizing systems. Acetaldehyde and formaldehyde can 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, acetaldehyde, benzene, toluene and total VOC rapidly reached low steady state levels that remained near ambient baseline levels of 10 to 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, like the MVP14™, MVP24™and MVP48™ 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.

  

Although no adverse effect from the use of UV hydroxyl generators have ever been reported, no toxicology studies have been published to verify this. Therefore, HGI conducted a comprehensive toxicology study with an industry leading clinical contract research company, Comparative Biosciences, Inc. (Sunnyvale, CA). 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 (GLP) 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 or cytopathology (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 presumably due to the decomposition of ammonia and other odiferous waste products. These results are applicable only to HGI Odorox® systems, which use UV energy 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 and 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**

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**Chairman HGI Scientific Advisory Board**

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