Using Hydroxyl Technology to dynamically sanitize air and surfaces on Cruise Ships

BACKGROUND

Minimizing the risk of bacterial and viral infections on cruise ships is an ever-present challenge. Of particular concern is the ubiquitous Norovirus. Norovirus infections on cruise ships can rapidly infect over 30 percent of passengers if not effectively contained. Norovirus is the most common cause of foodborne-disease outbreaks in the United States. Over 20 million cases are reported to the CDC annually.

Noroviruses are a group of viruses that cause gastroenteritis; an inflammation of the lining of the stomach and intestines, causing an acute onset of severe vomiting and diarrhea. Norovirus is very contagious and is spread by infected individuals who contaminate surfaces they contact and by the virus that is aerosolized from their vomit, stool and flatulence. Infections spread rapidly where people gather and there is increased person-to-person proximity and contact in facilities such as healthcare, schools, theaters and recreational centers. You can get norovirus from an infected person, contaminated food, water or air, or by touching contaminated surfaces.

Cruise lines are particularly susceptible to norovirus outbreaks because people are in very close quarters where they recreate and dine for extended periods of time. People can arrive onboard with the illness and be unaware since they can be contagious for days before being symptomatic and for two weeks after being symptom free. Outbreaks can originate in the food preparation and service areas where food workers become infected by touching contaminated ready-to-eat foods, such as raw fruits, vegetables and shell fish before serving them. Although there are several vaccines in clinical trials, there are no commercially available vaccines to prevent norovirus infection or drugs to treat it. Antibiotics have no effect on viral infections.

DYNAMIC AIR/SURFACE SANITIZATION

Cruise lines minimize the risk of norovirus outbreaks by implementing strict practices for personal sanitation and sanitizing and disinfecting surfaces, laundry, dishware, utensils etc. None the less, outbreaks occur. The spread of infection is a dynamic on-going process which static cleaning methods cannot adequately keep up with. The best way to effectively sanitize air and reach the multitude of potentially infected surfaces – including food stuffs being served – is with a dynamic method that simultaneously sanitizes both the air and surfaces while spaces are being occupied. To be effective, the method needs to have exceptionally fast and high kill rates in air, since aerosolized virus from public vomiting events is the single most effective means of transmitting the virus to large numbers of people. Within seconds of such an event, a microbe “cloud” spreading to a diameter of thirty feet develops and is

rapidly disseminated through the heating, ventilation and air conditioning system all over the ship. Norovirus stays viable and infectious in air for hours and up to several weeks depending on environmental conditions.

There are only so many ways to dynamically "clean" air and surfaces of bacteria, viruses and mold. These methods include:

- Adsorption on activated charcoal
- Ozone air purifiers
- Ionization and "non-thermal" ionic plasma air purifiers
- Ultraviolet (UV) air purifiers – photocatalytic adsorption
- Ultraviolet air purifiers – "germicidal" UV systems with wavelengths between 185-290 nm

Older systems used filters, adsorption, ozone, ionization and photocatalytic adsorption to remove particulates and decompose chemicals and pathogens and deodorize. Advanced analytical methods have enabled an objective assessment of the capabilities and limitations of these systems and found that they are not effective for treating large, occupied spaces.[1,2,3,4,5,6] The newest systems use ultra violet light (UV) to sanitize. UV light sanitizes in two major ways: by irradiating and killing microorganisms directly and by generating nature's most effective and safe cleaning agent – the hydroxyl radical oxidant (hydroxyls) – to sanitize even large residential and commercial spaces.[5,6]

An example of a technology that has proven effective killing bacteria and virus in air and on surfaces in occupied spaces is**HGI's Odorox® technology**, which uses high performance quartz ultraviolet optics to generate a powerful range of UV energy in a shielded chamber that kills microorganisms as they are circulated through the device. It also creates a cascade of airborne hydroxyls and other oxidizing agents from oxygen and water that safely and effectively kill bacteria, viruses and mold in the air and on surfaces in occupied spaces. Odorox® hydroxyls, which are the same as those formed naturally outdoors by the action of the sun, restore nature's balance indoors by destroying bacteria, viruses and mold in air and on surfaces and decomposing volatile organic chemicals, which are typically 4 to 6 times more concentrated indoors.

UV ENERGY – NATURE'S SANITIZING AGENT

The sun generates a range of UV energy between 185-290 nm that is absorbed by microorganisms. The UV energy damages the DNA of the organism and makes it incapable of reproducing. UV energy in that range also generates hydroxyls – a powerful oxidizing agent that kills a broad range of microorganisms. Atmospheric hydroxyl radicals are continuously produced by the action of the sun's radiated energy on water vapor and oxygen in our atmosphere. There are, on average, two (2) million hydroxyls in each cubic centimeter of ambient outdoor air during daylight hours. They are the main driving force behind the daytime reactions with hydrocarbons in the troposphere and neutralize most natural and man-made pollutants including greenhouse gases like methane, hydrogen sulfide and ammonia.

Atmospheric hydroxyls are also proven to kill bacteria, virus, and mold because they are able to react with the organic compounds like lipids, proteins and carbohydrates that constitute the microorganisms's cell membrane and disrupt its structure. The interior contents of the cells leak and the organism is destroyed. Conversely, humans, animals and plants have developed symbiotically with atmospheric hydroxyl radicals and thrive in their presence. Atmospheric hydroxyls are a critical component of nature's dynamic ability to provide environments that are free of harmful chemicals and pathogens.[5]Hydroxyls do not exist naturally indoors. They react within 20 to 50 milliseconds with the abundance of VOC and microorganisms indoors and are consumed near air entry points. In order to restore the balance of nature indoors and keep microorganisms to a minimum, hydroxyls have to be generated constantly.

SANITIZING WITH ODOROX® HYDROXYLS

HGI Odorox® systems sanitize just like the sun. They kill airborne microorganisms by exposure to high intensity ultraviolet radiation (185-290 nm) that is generated by custom quartz optics within the device as well as by the sanitizing agents that are produced by the action of the radiation on oxygen and water vapor. The formation of hydroxyls initiates the formation of a cascade of other powerful sanitizing agents which include organic peroxy and oxy free radicals. Together, these fast-acting oxidizing agents circulate throughout the treatment space and HVAC system to sanitize even remote surfaces, porous materials, fabric, skin, foodstuffs, etc. They react very quickly and do not accumulate. This same cascade effect occurs in nature and is safe indoors provided that the right concentration of hydroxyl radicals and by-products are formed initially.

The HGI Odorox® hydroxyl radicals are identical to those produced in nature. They are highly reactive radical transfer agents which rapidly react with and remove hydrogen atoms from the organic compounds, lipids and proteins that constitute the cell walls of microorganisms disrupting their structure. The cell membrane is damaged sufficiently for the contents to leak in a process called lysing, and the cell dies. The action is non-selective and is very effective against the cell walls of bacteria where 4 to 6 log reductions can be achieved within 6 to 12 hours for nearly all organisms. Kill rates of aerosolized microorganisms are higher than those for surfaces. Kill rates of 4 to 5 log reductions were measured for aerosolized gram positive and gram negative bacteria and selected virus in less than two (2) hours, which is exceedingly fast. The hydroxyl radicals are also effective against viruses and mold, which are often much harder to kill. Unlike other oxidizing agents like ozone and bleach, hydroxyls and their by-products do not damage fabrics, fade dyes, embrittle leather and plastics or damage electronics.

Hydroxyls are over a million times more reactive than bleach, ozone and other sanitizing agents. As long as the Odorox® system is running, the chain reactions persist. When the system is shut off, the hydroxyl radicals and other free radical oxidants dissipate rapidly.

EFFECT ON MICROORGANISMS

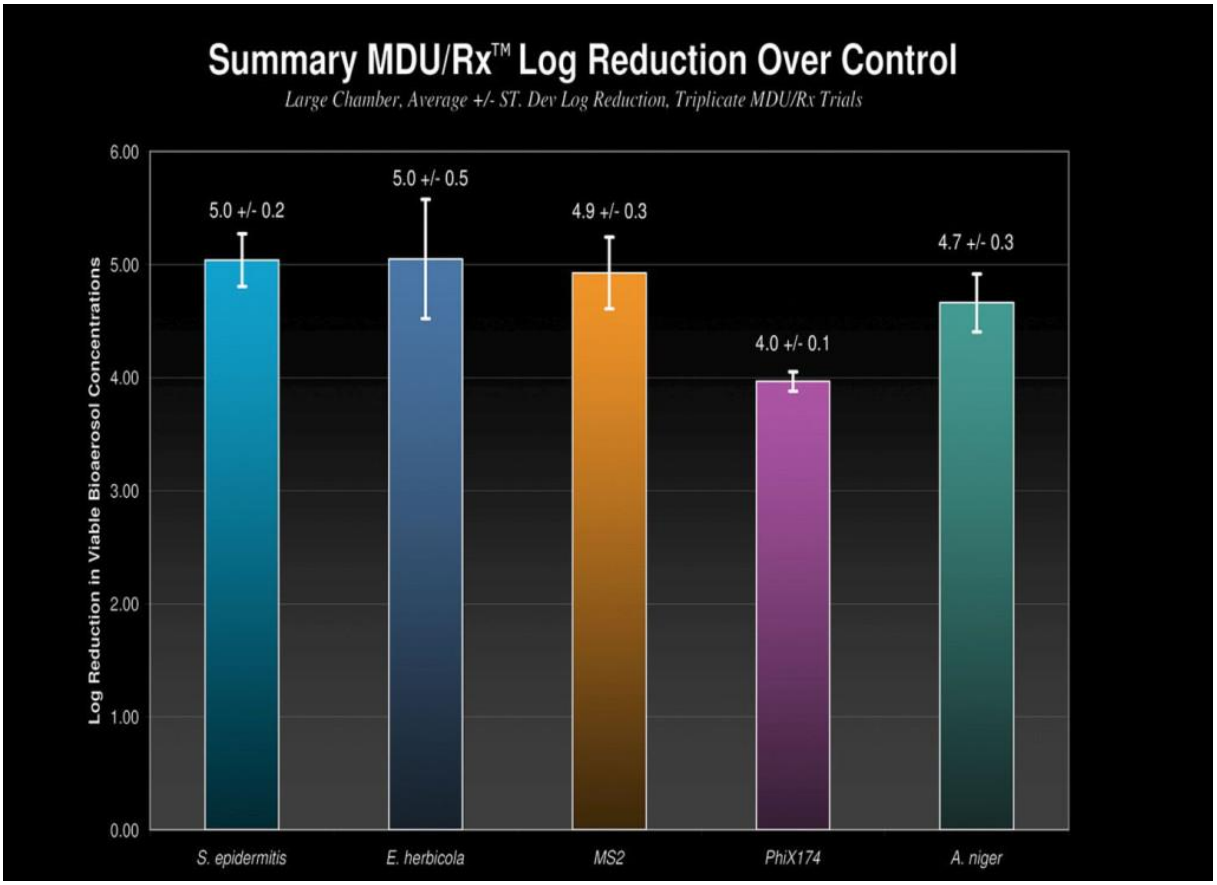
HGI Industries has commissioned a number of microbiological studies to evaluate the speed and effectiveness of their systems to eliminate a broad range of pathogens on non-porous and porous surfaces, in air and on plant

material. A sampling of results from a licensed testing laboratory, using pathogens commonly tracked by the EPA as representative of their type, indicated that substantially all of the following microorganisms were killed on stainless steel, glass and cotton fabric respectively, within the specified times summarized below. (Reports are available on request)

- Norovirus – 93.2% and 98.6% within 6 hours; CRE – 89.8% and 99.99% within 12 hours
- C. difficile – 99.8% and 98.6% within 48 hours
- Listeria – 94.7% and 98.6% within 48 hours
- Aspergillus niger – 99.9% and 97% within 48 hours
- Porcine Reproductive Respiratory Syndrome (PRRS) virus – 97.9% within 6 hours
- Pseudomonas aeruginosa – 99.99% and 99.9% within 4 hours
- Influenza A virus – 99.99% and 99.99% within 6 hours
- Staph. Aureus – 99.99% and 99.9% within 12 hours
- Methicillin Resistant Staph. Aureus (MRSA) – 65.1% and 94.4% within 4 hours

Recent studies on the reduction of bacterial and fungal pathogens on plant material from raw and sprouted barley processing were also conducted with similarly high kill rates. Plant materials were not damaged by exposure to Odorox® sanitizing agents. Hydroxyl radicals and their free radical by-products do not react with carbon dioxide and would thus not interfere with normal plant respiration. Hydroxyl radicals would however, react rapidly with plant respiration by-products like ethylene and neutralize them, which is beneficial to food storage.

The action of Odorox® hydroxyls on aerosolized microorganisms was conducted by ARE Laboratories in a specially designed stainless steel biocontainment chamber where very stable aerosols of representative gram positive and gram negative bacteria and selected virus and mold sampled could be maintained. Very high kill rates of 4 to 5 log reduction within two hours were measured for these aerosolized microorganisms. These results were reviewed by the FDA as part of the data set used to obtain FDA approval for the Odorox® MDU/Rx™ system as a medical device for sanitizing air in occupied medical facilities.



USING HYDROXYLS TO MINIMIZE NOROVIRUS ON CRUISE SHIPS

Norovirus is extremely persistent and can survive for weeks on hard surfaces, up to 12 days on contaminated fabric and months – even years – in still water. It has a textured surface structure that features antigen presenting sites and carbohydrate receptor binding regions. It lacks a lipid viral envelope. Standard soap/detergent cleaning methods are ineffective due the lack of a lipid coating. Bleach solutions of 2% to 8% can be used to sanitize given enough contact time. The Odorox® technology can safely deactivate norovirus particles by direct irradiation and by decomposing the antigen and carbohydrate surface sites as well as by disrupting the membrane structure sufficiently to cause the contents of the cells to leak.

Airborne hydroxyls and their family of oxy-radicals can effectively reduce norovirus contamination over 99% if used continuously and extensively throughout indoor cruise ship environments because they reach all surfaces accessible by air. Odorox® oxidants are effective on hard surfaces and a wide range of materials including skin, clothing, furniture, and especially raw foods in a way unachievable by other methods. Suggested treatment areas and approaches include sanitizing:

- Walk-in coolers
- Cooking areas

- Prep areas – plated uncooked food can be sanitized prior to serving
- Dining rooms
- Buffet areas
- Rest rooms, exercise and locker rooms
- Shower areas
- Entertainment/social areas
- Computer rooms
- Crew work, recreation and sleeping areas

EQUIPMENT AND USE OPTIONS

Hydroxyl systems have been designed for both consumer and commercial use. HGI systems come in a range of sizes, fan speeds and optic types tailored to treat spaces that range from 1100 cubic feet to two million cubic feet. Features you should look for include the use of heavy gauge steel in the casing and designs with strong wheels and sturdy, wide bases to facilitate moving the device without tipping. Systems should have easy to read indicator lights and some include variable optic and fan settings. Commercial systems should have the capacity to treat millions of cubic feet. HGI systems, for example feature up to 48 optics and include interactive process controls and remote monitoring capabilities to track system performance and ensure safety.

Maintenance should be simple. Systems should incorporate filters to remove particulates and minimize contamination of the optics. Maintenance is required for the optics and filters and varies with use conditions. Normally, optics are wiped with alcohol and lint free cloths quarterly and filters are washed and replaced monthly. In areas where there are high levels of volatile organic chemicals that can coat the optics, they should be cleaned monthly. Optics are typically changed after ~8,000 hours of use. Companies should offer training in the proper use and maintenance of its systems for optimal results and safe use.

SAFETY

The effectiveness and safety of hydroxyl sanitizing devices from different manufacturers varies widely. Each manufacturer should provide analytical data measured by independent, licensed laboratories to confirm the range of radiation generated and the amounts of hydroxyls and other oxidants being produced. The goal is to generate levels similar to those found in nature to ensure effectiveness and safety. Kill rates on surfaces and in air also vary widely for each device and should be measured by independent, licensed laboratories and provided by the manufacturer. The data should include surface and aerosol microbiological studies to prove efficacy and toxicology data to confirm safety.

HGI systems are ETL Certified by Intertek and meet stringent CSA and UL safety standards. The systems are fully shielded and incorporate two layers of angled vents to prevent radiation leakage and the intrusion of objects or fingers.

Ideally, the FDA should review and approve the use of each hydroxyl generator to ensure efficacy and safety. This is required for the device to be used in medical facilities. The FDA conducts the most stringent testing and its approval is the best measure of a system's capabilities and safety for use in occupied spaces. Most devices do not have this level of validation. An example of a hydroxyl sanitizing system approved by the FDA is the Odorox® MDU/Rx™ device, a representative Odorox® sanitizing system, which obtained FDA approval for use in occupied medical facilities. (FDA 510k # 133800, 2014). The data required by the FDA included chemical, engineering, microbiological and toxicology data, which were reviewed by a board of scientists which included organic and physical chemists, chemical engineers, microbiologists and equipment engineers, among others.

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