

HYDROXYL RADICALS -- HYPE OR REALITY

By Michael A. Pinto, CSP, CMP

The restoration industry is constantly changing and it is important for contractors and consultants to keep up with the latest equipment, materials, techniques, and approaches for resolving a wide variety of problems related to damaged buildings. One technology that has been migrating over to the restoration industry for the past few years is the utilization of hydroxyl radical generators as a complement to standard remediation of fire damage, water and sewer losses, and even mold contamination. Although this type of equipment has been available for over a decade, it has only been during the last few years that manufacturers have specifically targeted the restoration industry as a growth area for such equipment. As with the introduction of any unfamiliar work practice, this presentation to the restoration industry has resulted in some pretty aggressive comments from both proponents and detractors, a plethora of claims related to their effectiveness as well as scientific studies designed to support those claims, and a growing body of anecdotal data about their use.

This article is designed to offer an objective look at the technology of hydroxyl radical generators for restoration work as well as some professional opinions regarding their use. Given the range of comments in the industry regarding this equipment I feel it is important to offer these disclosures:

- I am a consultant to the restoration industry not a contractor, and, as such, I do not own a hydroxyl radical generator.
- The information provided in this article is a compilation of data from multiple manufacturers, end-users, research studies, and general science manuals.
- As a certified safety professional with over 30 years of helping people identify and control risk I have learned that you cannot just look at a piece of equipment and determine whether it is "good" or "bad"; it must be evaluated in conjunction with the people that are going to operate it and the environment in which it will be used.

The Science of Hydroxyl Radicals

As mankind has learned over the past three centuries, there is quite a bit that goes on around us that cannot be easily experienced by our five senses. For example, chemical reactions are occurring in the air around us on a continuous basis and, unless the overall volume of reactions gets to the point where we can actually smell something or feel an irritation of the eyes or throat, we continue on with our lives, blissfully ignorant of those processes. In an amazing design that keeps our world in balance, certain activities like fires, painting, and using internal combustion engines add to the amount of chemicals in the air, while other activities such as photosynthesis and rain actually reduce the amount of chemicals in the air. Over the last few decades scientists

have learned the importance of the role that ultraviolet (UV) rays play in removing undesirable substances from the atmosphere by triggering a variety of chemical reactions.

In the simplest terms, different wavelengths of light interact with water (and other chemicals) in the air and produce simpler byproducts known as reactive oxygen species (ROS). One of the main types of ROS is hydroxyl radicals which are typically formed when UV rays break up ozone and water droplets and recombine. This new chemical mixture is very unstable and within seconds seeks out other contaminants in the air (or on surfaces if the process occurs near the ground or indoors) to mix with. This mixing typically breaks down larger molecules (whether chemicals like volatile organic compounds [VOC's] or minute structures such as virus and bacteria) so well that scientists have dubbed hydroxyl radicals as the "detergent of the atmosphere".

Putting Science to Work for Restoration Contractors

Although the artificial production of hydroxyl radicals through the use of UV lights has been scientifically understood for a fairly long time, it is only in the last 10 years that this process has been harnessed for specific needs. Typically, portable hydroxyl radical generators utilize specific wavelengths of UV light to react with a metal surface coating to produce a large amount of hydroxyl radicals. Another process is to use ultraviolet light in conjunction with hydrogen peroxide to produce a mist that includes chemicals, ozone, and hydroxyl radicals.

As noted previously, a number of manufacturers have been aggressively pursuing the restoration market with their hydroxyl radical equipment and processes for deodorizing and sanitizing buildings as part of a restoration process. While the overarching science of taking a naturally occurring process from the out-of-doors and replicating it inside sounds great, a number of factors need to be considered before jumping in with both feet. One of the first questions to be asked is whether the hydroxyl radical generator produces ozone as a primary aspect of the decontamination process or even as a byproduct of equipment operation. Since UV lights are typically involved in the production of hydroxyl radicals, and since such lights naturally produce ozone, knowing how much ozone is being added to the environment is critical to safety. Currently, there are much more definitive regulations and guidelines controlling ozone in an air purifier than there are for hydroxyl radicals. (See, for example, the EPA publication entitled "Ozone Generators that are Sold as Air Cleaners", last updated March 31, 2011, and only available on the EPA website at <http://www.epa.gov/iaq/pubs/ozonegen.html>.)

Generally, if the hydroxyl radical generator is producing ozone at anything near the current FDA limits for ozone production from medical devices of 0.05 parts per million (ppm) in the air, I would not recommend its use in an occupied facility. Higher levels of ozone generation associated with remediation or decontamination using hydroxyl radicals would necessitate that

precautions be taken with items in the structure that can be deteriorated by ozone such as rubber, vinyl, and plastic, etc.

Working with Real Hydroxyl Radical Generators

Once a contractor has determined that a piece of equipment is an actual hydroxyl radical generator rather than an ozone generator masking as a hydroxyl radical generator, then the potential application for the device needs to be considered carefully. Is the primary purpose deodorization? Hydroxyl radical generators have been proven to be excellent at breaking down odors related to pets, fires, decomposition, grease and cooking, paints, and off-gassing of building products (although hydroxyl radical generators may have to be used for substantially longer periods of time if the source of the odor in the building is construction materials such as spray foam insulation, carpet, or mastic, which will continue to off-gas until the material is fully cured).

Does the contractor want to use the hydroxyl radical generator for sanitization? If so, there is good news on this front as well. Utilization of such equipment has been shown to be very effective in the destruction of bacteria and virus. Although there are claims that hydroxyl radical generators "destroy" fungal contamination, any contractor that buys into the marketing hype that they can take care of mold problems by using such equipment without removing porous materials that are colonized is heading for trouble. Even if the equipment kills the mold, dead mold spores and fragments are both allergens, as well as sources of mycotoxins, which can have harmful effects on the occupants. Since there is an overwhelming consensus within the current industry standard of care regarding removal of mold-contaminated porous materials, substituting treatment with hydroxyl radicals is outside the norm and could easily lead to liability issues.

When utilizing hydroxyl radical generators for deodorization or sanitization it is important to remember that the reactive compounds are very short-lived. Therefore, it is generally best to move the generator from area to area so that the hydroxyl radicals can come in contact with as many different surfaces and airborne chemicals as possible. Another approach is to utilize fans to quickly distribute air that is rich with hydroxyl radicals around the work area. Indeed, some manufacturers have hydroxyl radical generators that are designed to be paired with standard carpet drying fans to improve the distribution of deodorizing compounds produced by the generator.

Safety and Health Considerations

While there are always general safety considerations with any piece of electronic equipment, such as the potential for shock hazards, broken bulbs, etc., there are three specific safety and health concerns related to hydroxyl radical generators that should be understood. First and foremost is the issue of ozone that was touched on previously. This is significant given that a number of manufacturers are either intentionally mixing ozone and hydroxyl radicals in order to

find a faster deodorization process or have generators that produce a fair amount as an unintended byproduct. Advertisements for these machines are oftentimes craftily worded so that the remediation contractor has to pay attention to what is implied as well as what is said. For example, some manufacturers trumpet that their equipment as producing hydroxyl radicals and "activated oxygen". While this may sound impressive the term activated oxygen is used so that they do not have to say that their machine produces a fair amount of ozone as a byproduct. There is no doubt that elevated levels of ozone, even for short periods, are detrimental to health. There's also fairly good evidence that low levels of ozone over an extended period of time can be unhealthy. As such, contractors should not use hydroxyl radical generators that produce levels of ozone above 0.5 ppm in occupied structures.

A second potential health concern related to the use of hydroxyl radical generators centers around hydroxyl radicals inside the body. Certain chemical processes can produce hydroxyl radicals without UV light. When this happens inside living organisms they are known as "free radicals" which are damaging to cells and organs. While medical literature is pretty clear that airborne hydroxyl radicals are blocked by the skin, concerns have been raised in the past regarding the inhalation of airborne hydroxyl radicals and whether that could trigger the formation of biological free radicals. Although there still are some mixed results in regards to research, especially from European studies, there is a growing body of evidence that exposure to airborne hydroxyl radicals does not lead to extensive free radical development inside the body.

The third specific safety/health concern related to hydroxyl radical generators is probably the most important. The very effectiveness of hydroxyl radicals in breaking down larger molecules means that a series of chemical reactions is taking place as the equipment operates. Over time more and more hydroxyl radicals are produced and keep working on the chemical compounds until they are broken down into inert materials. The interesting question from a safety and health standpoint is whether it is safe for individuals to be in an area where hydroxyl radicals are breaking down airborne chemicals when we cannot be sure of the types and levels of intermediary products being produced.

Nor is this just a theoretical argument. Studies of levels of indoor air pollutants that are subjected to ozone treatment have shown that overall levels of some hazardous materials actually increase while the chemical reactions are underway as many pollutants have to be broken down four or five times before they become safe. Given that hydroxyl radicals work in a similar fashion, there is reason for caution even though the manufacturers proclaim that hydroxyl radicals are safe for "people, pets and plants". While there is good evidence to support their claim that exposure to hydroxyl radicals is safe, that is a different question than whether it is safe to be in an atmosphere with a relatively high level of chemical compounds that are being broken down by hydroxyl radicals. Since such equipment is often used to deal with objectionable odors

there is pre-existing evidence that elevated chemical levels are present or else an odor would not be detected.

A Number of Approaches to the Use of Hydroxyl Radical Generators

Given the documented positive benefits of using a hydroxyl radical generator, it is certainly a piece of equipment that restoration contractors need to understand and consider adding to their toolboxes. The \$64,000 question is what procedures the company puts in place to control its operation so that both its own workers and the occupants of buildings where the equipment is utilized are protected.

When a good understanding of the equipment and science of hydroxyl radical generators is matched with logical thinking, three specific approaches to internal operating procedures when using such equipment quickly emerge. These can be thought of as aggressive, moderate, and conservative approaches. Of these three the conservative attitude is the easiest to understand and implement. Since we do not know all of the chemicals that are in the air that we are trying to address with the hydroxyl radical generator, and we do not have complete information on all the health concerns of either the occupants or workers, the conservative approach is to limit the use of hydroxyl radical generators to areas that are unoccupied. This allows the equipment to be used in many environments but puts a premium on protecting the health of workers and occupants.

The moderate approach still places a high premium on the health of workers and occupants but is a bit more nuanced in regards to the science. Understanding that hydroxyl radicals will eventually break down airborne contaminants, the moderate approach limits the use of such generators to unoccupied areas for a set period of time at the start of their use or until there are no noticeable odors left. Even though people are restricted from entering the work area during the initial operation of the generator, they can go in with the machine still running after the most extensive chemical reactions have occurred. This approach takes advantage of the long-term benefit of having a hydroxyl radical generator running even after the odors are gone to deal with any contaminants that enter the air from sources that could not be physically removed. Contractors utilizing such an approach will often do their initial demolition and tear out to expose source materials then install the generators overnight so that the most extensive chemical reactions occur while no one is present in the structure.

The aggressive approach is to assume that hydroxyl radical generators are completely safe to use in occupied environments and run them without any restrictions. While this approach may be the most beneficial to the equipment manufacturers and contractors who are always on a deadline, it does carry some risk. Anyone who has been in the restoration industry long enough remembers when the manufacturers of ozone generators were also claiming that their units were safe to operate in occupied environments. Some manufacturers even went so far as to claim that

elevated indoor ozone levels were healthful rather than being a detriment. Alas, it took years of study, numerous pronouncements from the EPA, specific regulations from California and other states, and the bankruptcy of the largest manufacturer of ozone air purifiers for some individuals to learn that the aggressive stance in that case actually put their organization at substantial risk.

Understand the Basics, Develop Appropriate Procedures, Watch for Future Developments

The reality of the situation surrounding hydroxyl radical generators is that they are not the silver bullet that will solve all the restoration contractors' problems. Still, they can be an important tool as long as they are utilized in a thoughtful way with proper training, just like any other powerful piece of equipment that come with the promise of improved performance and faster completion of projects. But they also carry some risk, which is why restoration contractors need to understand what they are using, which situations are appropriate for hydroxyl radical generators, and how they are going to protect their workers and building occupants during their use.

As a final thought, contractors should always remember that if they start with a conservative or moderate approach in regards to the use of hydroxyl radical generators, they can always get more aggressive if future information clearly indicates that the potential risks presented here are unfounded. However, if they choose to adopt an aggressive stance and later information shows that more caution was necessary they may have unnecessarily impacted the health of their workers or their clients.

About the Author

Michael A. Pinto, CSP, CMP, is chief executive officer of Wonder Makers Environmental, Inc., a manufacturing and environmental consulting firm that specializes in identification and control of asbestos, lead, IAQ, mold, industrial hygiene, and chemical problems. Mr. Pinto is the author of over 150 published articles and several books. He completed doctoral course work in environmental engineering and holds numerous certifications in the environmental and safety areas, including Certified Safety Professional and Certified Mold Professional. He was selected as part of the Mitigation Assessment Team for FEMA following Hurricanes Katrina and Rita and was a contributor to the EPA's Healthy Homes Initiative. He has worked closely with the restoration industry for the past sixteen years and been part of its development with a group that deals with hazardous contaminants as well as safety concerns such as fires and floods. This broad perspective has allowed him to integrate concepts from a variety of industry groups into a synergistic process which produces documentable results.

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