

Photohydroionization™ PHI™

An Advanced Oxidation Technology



The history, evolution, validation, case studies, pilot plants and product lines utilizing Photohydroionization™ for water, food, air, laundry and grease treatment.

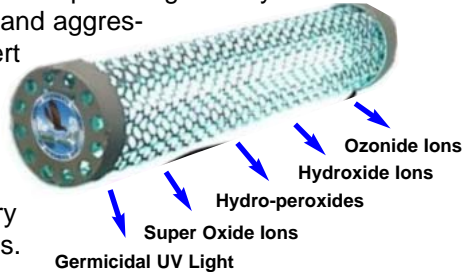


Photohydroionization™ - An Advanced Oxidation Technology

By Ronald G. Fink

Summary

Photohydroionization™, or PHI™, is an Advanced Oxidation technology developed and owned by RGF Environmental Group. Basically, it is a broad spectrum high intensity UV light targeted on a quad metallic catalyst ultraviolet (UV) target in a low-level ozone and moist atmosphere. This creates an advanced oxidation process providing friendly oxidizers, or very safe and aggressive oxidizers that revert back to oxygen and hydrogen. PHI™ Technology has been successfully used in water, air, food, laundry and grease applications.



History

Experiments with food and water irradiation started in the 1960's (RGF employees participated in this work). Results were promising. However, food irradiation remains a problem to date. This is due to inconsistency in results, some taste concerns and mostly public fear of radiation. Irradiated food must be labeled as such, and the radiation symbol carries public concern.

In 1985 RGF formed with the corporate mission to provide the world with the safest water, food and air without the use of chemicals. Experiments with ozone (O₃) and UV light rays proved promising. UV light at 184 NM creates a low concentration of ozone. This low cost, low maintenance method of producing ozone was of commercial interest. However, the low concentration was an efficacy concern. Experiments were conducted by RGF's R&D in the late 1980's, and it was discovered that the use of UV ozone on industrial wastewater was feasible when the low-level UV ozone was activated with UV light, thereby producing a hydroxyl radical, the most powerful friendly oxidizer. This was an important find as the use of ozone was preferred. However, the traditional method of ozone production was the corona discharge or "CD" method, which produced a high concentration of ozone. The CD method was considered not practical due to high cost, high maintenance and high failure rate.

This find led to an 18 year string of discoveries involving: advanced oxidation, utilizing UV irradiation, ozone, fenton reagents, catalytic oxidation, hydro peroxides, titanium-silver-rhodium and copper catalysts, silver ions, oxide ions, super oxide ions, ozonide ions, broad spectrum UV radiation, soft surface irradiation, hydroxide ions, radiated catalytic ionization™, hydroxyl radicals, HE-UV, sintered metal targets, PPC-UV coating, photocatalytic oxidation, photohydrocatalytic™ oxidation and the PHI™ Cell, resulting in numerous patents and over 500 RGF products.

Development

UV light and ozone are not new discoveries. Ozone was first discovered in the late 1800's and used as a water purifier in Europe. UV light was discovered in the 1930's. Actually,

nature discovered it before; it was called the "sun". The disinfection qualities of UV light are also not new. Hospitals have used UV light for decades in operating rooms. Barbers were disinfecting combs in the 1950's with UV light. What is new is the enhancement of both these natural, friendly oxidizers and the validation for use on air, water, food and laundry.

History of Water Systems

The first patents awarded to RGF were for its industrial wastewater treatment systems. RGF pioneered and developed both the discharge and recycling systems for heavy industry. By the mid-1980's, environmental concerns were peaking and RGF's systems were the industry choice. RGF maintains strategic alliances, national accounts and distributorships with many Fortune 500 corporations, including Caterpillar, John Deere, GE, Halliburton, Hertz, NASA, US Department of Defense, US Army, Navy, Marines, Air Force, Baker Oil, Waste Management, Laidlaw, Case, US General Services Administration, Hilton Hotels, FPL, US Nuclear Regulatory Commission, Schlumberger, Steris Corp., Food Safety Systems, ADM, Conagra, Seaboard Farms, Kraft, Coca Cola, Insinkerator, McDonalds, Regal Foods, Shaklee Corp., Sandia National Labs and Nevada Nuclear Test Site. All of the industrial water systems used RGF's advanced oxidation (ozone/UV) systems with great success. RGF water systems have been manufactured since 1985 with over 20,000 water systems installed in 33 countries.

About Ozone

Ozone or O₃ is the result of oxygen (O₂) reacting with an electrical discharge such as lightning, a spark, or an electrical current, or UV light radiation. Ozone is a colorless gas that has an odor similar to the smell of fresh air after a thunderstorm. Ozone is extremely unstable and cannot be stored. It must be generated at the site. Ozone is faster and more powerful than chlorine and is an oxygen-based friendly oxidizer. By friendly we mean oxidizers that revert back to oxygen and hydrogen after they react. High levels of ozone can be a health hazard or even lethal.

History of Air Systems

In the mid-1980's air purifiers started to make their way into the residential market. Ozone air systems were widely used in the commercial restoration business for fire and flood damage to buildings. These applications utilized corona discharge systems (CD) that use a spark or electrically charged plates to simulate lightning. This converted the oxygen (O₂) to ozone (O₃). The CD method creates very high concentrated ozone. Plus by using air as the oxygen source, you are receiving 20% oxygen and 80% nitrogen. The problem with CD systems is with oxygen conversion you also get a nitrogen conversion, which makes nitric acid and nitric oxide. Therefore, most professional CD manufacturers provide oxygen generators (as does RGF) with their systems to prevent the nitric problem.

The problem facing the residential air systems was that the cost of an oxygen generator was so high they went without one. This, of course, created a CD unit that produced high concentrated ozone plus low levels of nitric oxide and nitric

acid. Maintenance was a problem due to the corrosive nature of nitric acid and the high concentration of ozone exceeding the Federal safety limits of .04 ppm. Ozone readings at the exhaust have exceeded 10 ppm, which is potentially lethal. RGF decided to stay out of this dangerous market and stay with our ozone commercial market which only used our equipment in evacuated buildings controlled by professionals.

In the late 1980's we discovered that the lower concentration of ozone could have an effect on odors, mold and bacteria levels as low as .02 ppm (half the Federal safety maximum) were reported as having significant results. Testing this theory, we determined that safe, low levels of ozone could provide a significant reduction in airborne mold, odors and bacteria. The challenge was to create a safe residential air purifier that could produce safe, low concentrations of ozone that would not exceed the .04 ppm Federal limits. This was accomplished in the early 1990's, at about the same time the Federal Government was going after the CD ozone residential units. This battle of the Feds and CD manufacturers gave ozone a very bad name.

With the technology to build a device that produces safe, low concentrations of ozone and the ability to ensure a room would not exceed .04 ppm, RGF set out to validate the use of this device on mold, VOC's, odors and bacteria. Fox TV News was doing a three-part series on indoor air problems and asked us to test one of the CD ozone units. The unit they gave us was producing 18 ppm ozone, a lethal amount that drove the camera crew and news reporter right out of the office. The Fox people then asked if they could independently test our RGF Pure Air unit. They ran tests supervised by an independent air specialist and two medical doctors. The series turned out to be a fantastic infomercial for RGF. The results couldn't have been better. Fox ran this on their national news network and their national health news. Popular Science picked up the story for the magazine and ran it on the Popular Science TV Show. Sales of our Pure Air residential line picked up substantially.

In the mid-1990's, a high-end resort island approached us about water and air problems on the island. The resort was called Little Palm Island. It is a five-acre island located 30 miles from Key West. The island was formerly President Harry Truman's fishing camp. It was also the site of the film "PT-109", the JFK World War II story. The island maintained the original Truman House for the restaurant and had 32 thatched huts for rooms. With the high humidity and the inherent problems associated with an island, environmental problems such as mold and mildew were everywhere.



The rooms had sick building syndrome. The food storage rooms and kitchen were mold havens. Sewage was being injected into a sewage injection well. The sewage processing plant was over its capac-

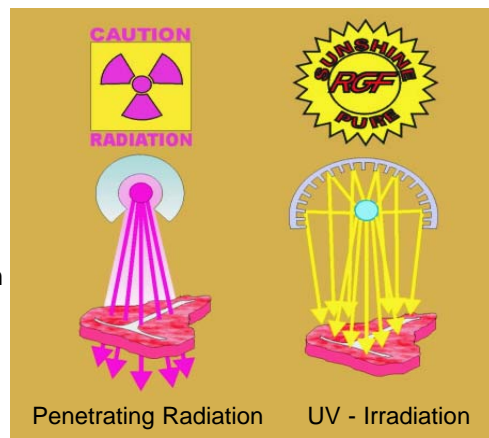


Little Palm receives EnviroVision Plaque

ity. Drinking water was stored in underground tanks. Garbage odors were a problem, as it had to be stored on the island and shipped back by boat. With the use of our newly discovered Advanced Oxidation Technology, RGF was able to provide 19 systems to greatly improve the island environment. We called the project "Envirovision®". With the RGF Advanced Oxidation processes, we were able to provide the island with the purest possible water, air, food and laundry without the use of chemicals. This was the first time RGF was able to utilize numerous systems to cover all four areas: food, air, water and laundry.

The Little Palm Project gave us a few new problems - food, sewage and laundry. Little Palm, being an island, offered a mold, mildew, odor, sewage and bacteria problems like we had not seen before. Food shelf life was short, mold grew on the walls, and airborne mold spores and bacteria were heavy. In the food storage areas, the food needed a chemical-free method of sanitation. Reflecting on food irradiation experiments of 40 years ago and the associated problems with radiation, it was ruled out. The food problem was a surface contamination problem resulting from airborne mold and bacteria in a very growth-friendly atmosphere (warm and humid). Penetrating radiation was overkill. Why penetrate through a food item when the contamination is on the surface? Accordingly, we tried soft radiation, or non-penetrating radiation like sunlight or UV radiation.

Straight 254NM UV, sometimes referred to as germicidal UV, works well on surfaces. Subsequent experiments found that creating an advanced oxidation atmosphere between the UV lamps and the food surfaces or photoionization provided fairly broad kill rates of over 90%.



In addition, we provided ozone/water food wash down stations. Ozone gas dissolved in water is a very aggressive and friendly disinfectant that also removes chlorine and pesticides from fruits and vegetables.

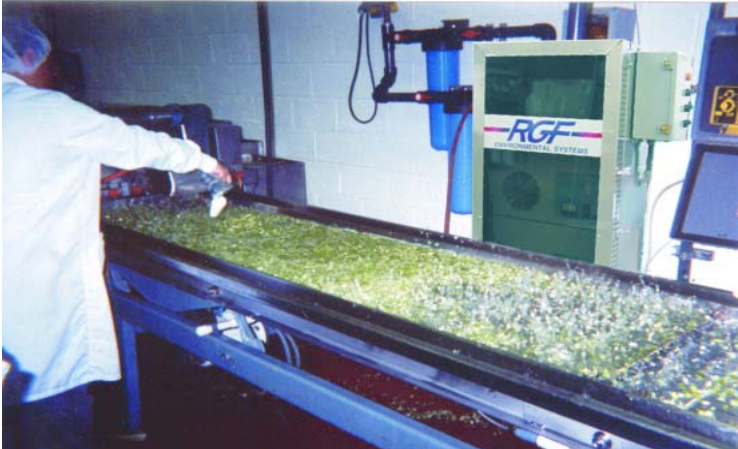
The sewage plant was another unique problem that our PHI technology helped us with. The plant was overloaded and the injection well was under designed (installed by the Trumans in the 1940's). In order to increase the efficacy of the plant, we added fluidized bed technology to the existing plant. Also, we treated the restaurant grease separately. We discovered that the PHI Cell's advanced oxidation gas actually broke the grease down to a food source for the bio plant, which created an interesting scenario. Instead of grease adversely affecting the plant's operation, the PHI treated grease improved the plant's efficiency. To relieve the overflowing injection wells, we installed a sewage reclaim system using the PHI Cell to sanitize the water for irrigation. This system not only helps save the island's natural environment, it provides a highly nutrient rich water source to the island's plant life saving over \$100 per day in irrigation costs.

Pork: RGF has reduced surface bacteria by 80% and increased shelf life up to 20% at one of the nation's largest pork producers.

Pork and Beef Brine Injection: RGF has reduced bacteria up to 99% at a beef and pork processing plant.



Vegetables: RGF has reduced surface bacteria on corn, peas, carrots and celery by more than 90% at a number of vegetable houses.



RGF's Advanced Oxidation of Celery

With these successful applications, RGF formed a strategic alliance with BOC, a \$7 billion NYSE food processor supplier. The vast food industry would require a world-class food sales and support team second to none. BOC had it. More recently, BOC has purchased five RGF PHI technologies for the food processing industry in the USA and Canada. RGF will continue to work with BOC with manufacturing and future food inventions under an engineering services contract.

In the late 1990's a group of Shaklee executives came to RGF. (Shaklee is a multi-level marketing company with a 40-year history. They enjoy a good reputation and are primarily concerned with health and nutrition). They were interested in getting Shaklee in the air purification business. Shaklee, owned by a Japanese pharmaceutical company, is extremely conservative and cautious with new technology. They had seen our old Fox TV News video after visiting our facility, and were convinced we were perfect for Shaklee. It took over one year of validation testing, lawyers and more testing. Shaklee finally launched their AirSource project. The unit contained an RGF Photoionization Module and another technology for par-

ticulate removal. The results were outstanding. Shaklee's sales were over \$50 million retail the first year. Customer satisfaction was very high. Basically, the entire project was a huge success.

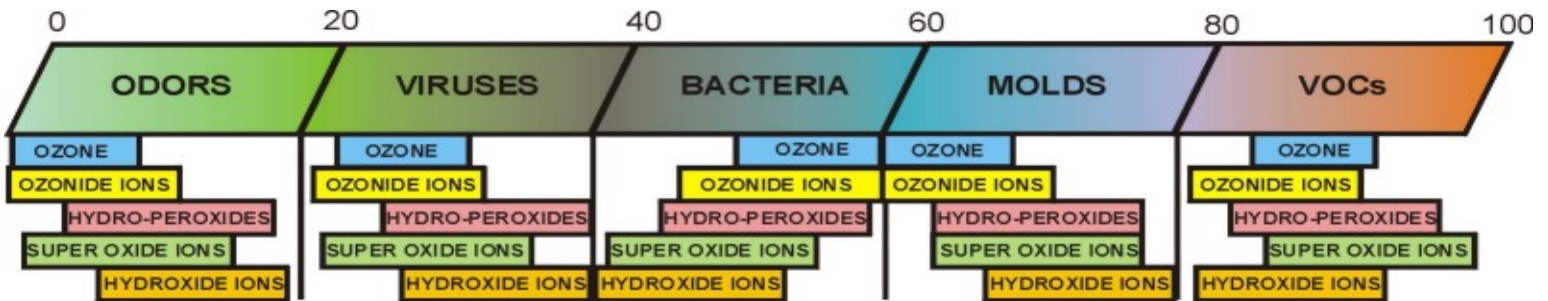
R&D continued on our PHI Technology with the goal of reducing ozone levels and creating alternative advanced oxidizers. In 2003 the PHI Cell was developed. The original PHI Cell was designed for use in a central HVAC system. This provides the fastest and most effective oxidizer distribution. Rhodium as an additional catalyst as well as improved hydration compounds were also added. Plus, a totally new target



concept was used. A 360° cell of faceted expanded metal providing maximum exposure of the catalytic surface. Also "PPC", a poly protective cover, was added to protect from bulb breakage and resulting mercury spill, as all UV bulbs contain mercury. A broken bulb in a food establishment or in an HVAC system where the mercury could end up on the heating wires or burner where it could volatilize would be disastrous, to say the least. New laws in 2004 require manufacturer to label all packaging with "Contains Mercury".

The bulb was reworked and an RGF HE/UV Broad Spectrum 100-300-NM bulb with a heavy duty filament was developed. This combined with a soft start ballast and the insulating qualities of our PPC gave the new PHI-Cell an unprecedented 3 year, 25,000 hour life. This was a major improvement over the current standard 8,000-10,000 hour UV bulb life. The most important improvement was the efficacy, the new cell design created more hydroperoxides, super oxide ions and ozone levels were .01-.015 ppm. Country or forest air is .01-.02 ppm of ozone. Most people can smell ozone at .01 ppm, and .05 ppm is the federal safe limit for medical devices. The new cell also produces hydroxide ions and ozonide ions which broadened our scope of capabilities. (See chart below)

By using a PHI Cell with redundant oxidizers our scope of



Organic Spectrum

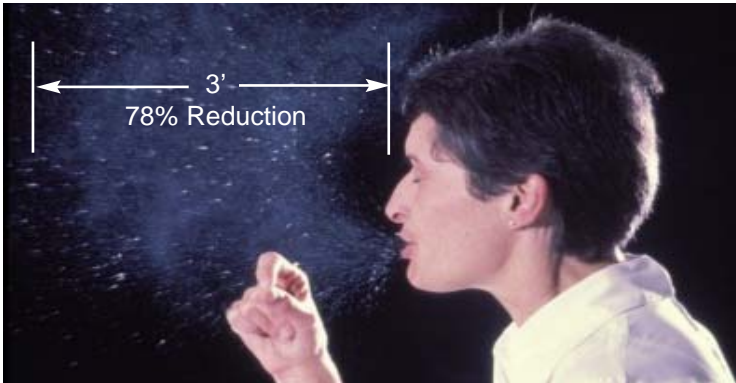
Effectiveness is widely broadened with Multiple Oxidizers

Riviera company enlisted to fight off SARS in China

effectiveness is widely broadened.

The SARS virus was a major concern. Our Representative in China worked with the Chinese government and tested the cell. This testing proved positive that the PHI Cell could help contain the SARS virus by making a kill at the source. Most air purifiers require the contaminant to actually enter the purifier. With the PHI-Cell the oxidizers are distributed throughout the room. With this in mind and our success with mold, VOC's, bacteria and odors, we started looking for a way to test common "microbials" or "germs".

Four years ago, BOC brought in Dr. Marsden, a well known Food Scientist and Professor at Kansas State University. Dr. Marsden has been instrumental in validating our food sanitation systems. He has recently formed a new company "Food Safety Systems, L.L.C." Together with his team of experts, they provide consulting to the food industry with food safety science recommendations. They are also working with Sandia Laboratory in New Mexico, a National Laboratory responsible for Homeland Security. A meeting was held at RGF with Dr. Marsden's group. Virus and bacteria transmittals were discussed as well as the PHI Cell's ability to kill airborne viruses and bacteria at the source. A testing protocol concept was



discussed which included a "Sneeze Simulation Machine" and "Sneeze" chamber. A sneeze can travel at up to 100 mph, so we had to consider lung capacity, sneeze pressure, and liquid volume to properly simulate a human sneeze. This was accomplished and the test proceeded with outstanding results. An average of 78% reduction of microbials was achieved in a double blind test, at 3 feet from the sneeze source. This is clearly not a medically supervised test or protocol. However, from a practical point, it was definitely providing some kill at the source and will provide some level of protection.

The physics of PHI as an air purifier is unique. A PHI System is not a filter or an ozone generator. It is a cell that radiates

OXIDIZERS (In order of strength)

- | | |
|-----------------------|-------------|
| 1. Fluorine | 6. Chlorine |
| 2. Hydroxyl Radical* | 7. Bromine |
| 3. Ozone* | 8. Iodine |
| 4. Hydrogen Peroxide* | 9. Oxygen* |
| 5. Permanganate | |

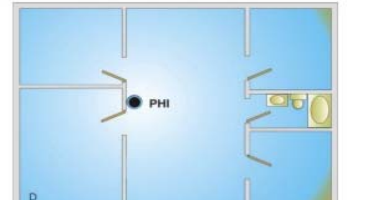
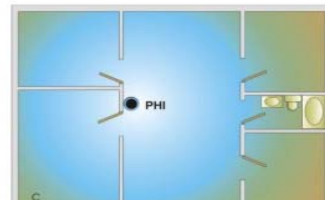
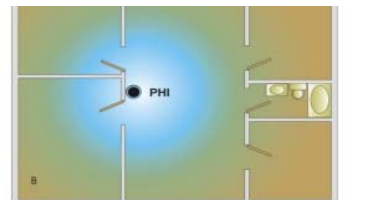
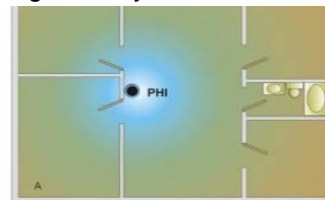
* Elements of the RGF Advanced Oxidation Process. Friendly oxidizers do not use chemicals and revert back to oxygen and hydrogen.

friendly oxidizers.

These oxidizers travel through a room or home by Brownian Motion (natural air movement). One of the five PHI oxidizers is hydro peroxides. In layman's terms, treating a room with hydro peroxides is like misting a room with a weak hydrogen



peroxide (H₂O₂) mist. Each time a hydrogen peroxide particle finds an airborne organic contaminant it will oxidize or neutralize the contaminant, and in the process kill itself. The hydrogen peroxide particle (H₂O₂) will revert to water vapor (H₂O). This will permit the next H₂O₂ particle to move a little further into the room until the entire area is purified. This is the reason one small PHI unit can work on large areas up to a 5,000 sq. ft. house. The factor is time. The more pollutants or contaminants, the longer it may take to reach a 90%+ reduction level.



Restaurants

The PHI Cell and technology have been widely used in our Restaurant EnviroVision Program. This program provides a restaurant with the purest water, air and food possible without the use of chemicals. Typical PHI Systems used at restaurants include:

- Food Sanitizer
 - Grease Sewer System
 - Food washing
 - Air Filter System (grease, VOCs and odors)
 - Ice machine Sanitizer
 - HVAC Systems
 - Compactor Odor / Bacteria
 - Restroom Bacteria / Odor
 - Potable Water Systems
- The benefits include:
- Longer food shelf life - up to 40%
 - Safer food
 - Airborne grease, odor and bacteria reduction

- Reduced legal liability
- Positive public image
- Improved worker safety



Restaurants participating in this program receive a commemorative plaque and a "We Care" Door Decal.

