

# WHITE PAPER

## EFFECTS OF ULTRAVIOLET OZONE FOR AIR, ROOM AND DEEP CLEANING DISINFECTION PURPOSES

By TOMI Environmental Solutions, Inc.

According to the EPA and American Medical Association (AMA), studies indicate that indoor levels of many pollutants may be 25 times and occasionally more than 200 times higher than outdoor levels. While older buildings present the issue of a large buildup of contaminants over time, today's buildings are built so air tight that the health risks may be even greater. According to the EPA, people spend 90% of their time indoors and in the last 30 years, the number of people with asthma has gone up by almost 60%.

Ozone is one of the strongest oxidizers known to man. TOMI<sub>ES</sub> has raised the bar for indoor air sanitizing with the use of UV produced ozone to destroy VOC's (Volatile Organic Compounds) or odors, eliminate smoke and reduce allergy- and asthma-causing contaminants that ordinary cleaning can leave behind. In addition, air sanitizing will kill mold spores, bacteria, eliminate pet dander, dust mites and inactivate viruses such as H1N1 (Swine Flu).

The use of UV ozone has been tested in many field trials in tens of thousands of commercial as well as residential buildings and the results have been examined by many Industrial Hygienists. TOMI Environmental Solutions co wrote the first protocol ever used in a Leed Accredited building. UV ozone was applied to a 400 million dollar plus 30 story Leed Accredited large commercial building in Manhattan, New York to eliminate smoke odors and carbon stemming from a fire that broke out before the building was completely built out. Industrial Hygienists not only found that carbon was eliminated from the building, but the carbon bond was broken. The job marked the first time UV ozone was used in a Leed Accredited Building to eliminate the contaminants. Michael Rabil, Rolyn Companies has stated "We selected TOMI<sub>ES</sub> because their equipment and technologies have produced results that exceed anything that is on the market today. It is exciting to see any industry take a quantum leap in its ability to service its customers and we believe that TOMI<sub>ES</sub>'s equipment and training will provide just that, a revolutionary change in how companies can now attack indoor air pathogens in a green, cost conscious and totally effective manner."

### **The Use of UV Ozone for Environmental Restoration**

The U.S. Environmental Protection Agency ranks indoor air pollution among the top-five environmental risks to human health. According to the California Air Resources Board, also known as the CAARB report, states "Americans spend 90% of their time indoors." Premature deaths, lost worker productivity and medical treatment due to indoor air pollution cost the state of California alone \$45 billion a year. Approximately 532,000 (39%) of the 1.36 million cases of doctor-diagnosed asthma in the U.S. involving children under the age of six could be prevented by eliminating exposure to indoor pollutants and allergens in housing, according to the Journal of Pediatrics.

## **UV-Generated Ozone**

Over the past decade, virtually all service-restoration companies have utilized traditional destructive methods to deal with indoor contaminated properties. Such methods include the use of potentially toxic biocides that are applied by fogging or spraying or are hand-wiped on floors, walls, counters, furniture and HVAC systems. The theory is that the biocides will kill a wide range of microbial organisms that include fungi, bacteria and viruses.

Few, if any, claims are made regarding the efficacy of biocides against “biofilms,” a polysaccharide adhesive matrix that protects most bacteria and many fungi from outside influences. In addition to biocides, most traditional restoration companies employ portable HEPA units to scrub the air of fugitive spores and other fragments. Both biocides and portable HEPA have limitations that may still render the property uninhabitable even after their deployment.

The use of biocides acts as a chemotherapy of sorts for surfaces contacted in the property—that is, the use of a toxic material to destroy another organism where, in fact, the cure may be worse than the microbe or cell that it is trying to kill.

For many individuals, entering a property after the application of a biocide results in irritation and respiratory distress. Volatile organic compounds (VOCs) produced by many biocides linger for days. Few restoration companies ventilate properties sufficiently after biocide application. Portable HEPA, while somewhat effective for elevated airborne spores, often miss organisms and fragments that have settled to the floor or furniture, and as such are no longer airborne.

## **Ozone Alternative**

The use of ultraviolet (UV)-generated ozone properly sized and placed within an indoor environment in the absence of humans, pets and plants—with elevated levels of bacteria, fungi, allergens, viruses and VOCs—provides an effective method to inactivate a significant percentage > 79% of these organisms within four to twelve hours of application and up to 97% if used longer. Additionally, UV generated ozone at levels of 10 to 12 ppm will penetrate biofilms and destroy bacterial- and fungal-protected colonies. UV-generated ozone also has the added advantage of reducing or eliminating offensive odor created by a wide variety of indoor conditions.

Proper use of UV-generated ozone includes correct placement of the units to ensure total saturation of ozone throughout the property, including the furnace air intakes. During the application of UV-generated ozone, measurements are required to ensure that sufficient levels have been reached. Following the application, the property is ventilated and air testing is conducted to ensure that the ozone levels are below the threshold limit value.

In properties that have microbial contamination, spores, fragments and particles will drop to the floor or furniture due to gravity, attachment to dust and through the application of ozone. It is necessary to HEPA vacuum the entire property after an ozone application to remove all dead or damaged particles.

Environmental laboratory samples should be taken before treatment to establish a baseline and after ozone application to validate the effectiveness of ozone treatment. Additionally, it is advisable for companies offering ozone remediation services to develop and document the ozone remediation process, including support of trained medical personnel, scientists and industrial hygienists.

While some properties severely damaged by flooding require the removal of water-impacted building materials and rapid dry-out techniques (an important role for traditional water restoration companies), the use of UV-generated ozone in the final stage of cleanup presents an important treatment option. For contaminated properties not directly impacted by flooding, UV generated ozone is an effective stand-alone treatment with a higher level of microbe destruction than the current use of conventional biocidal chemicals.

Ozone treatment thoroughly saturates an indoor environment while the use of biocides and portable HEPA are used in select areas of the property thought to have contamination. Most restoration companies will treat what they see, but bacteria and fungi below visual detectable levels less than 50 microns may occupy numerous areas of the property and thus escape traditional methods. The worst outcome of a restoration effort is to miss the objective (high percentage removal of micro-organisms) and lead the client to believe that the property is safe to occupy. For biocides to be truly effective, the entire property would need to be saturated, which would likely render the site off-limits for days or weeks while the chemical constituents of the biocides dissipate.

UV-ozone, on the other hand, fills the property in hours and is then quickly ventilated out by properly trained technicians. Occupants can return as soon as the ozone levels are at 0.03 ppm or less, which takes about 45 minutes on average.

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## **UV Ozone used as a Disinfectant for Fungal Contamination**

**UV Ozone was used in a case study in Massachusetts at a residence to eliminate fungal contamination in the air.**

### **Case study:**

Indoor air review for fungal contaminants pre-and post TOMI<sub>ES</sub> "UV Ozone Deep Cleaning".

### **Subject property:**

The subject property is a residential structure located in Winchester Massachusetts (henceforth referred to as subject property). The address and photographs of the subject property have been omitted from this case study to maintain the privacy of the owner.

### **Hypothesis:**

TOMI<sub>ES</sub> UV Ozone Deep Cleaning can be an effective disinfectant, useful for the removal of fungal contamination in air.

## **Background:**

In October 2008 the client contacted the IEP prior to purchasing a unique village property in Winchester Massachusetts requesting a preliminary inspection of the subject property. The client requested the inspection be performed in a noninvasive fashion, based on casual visual observations, during a walk through. The purpose of the inspection was to identify potential household environmental hazards and make recommendations for testing.

The subject property was originally constructed in 1850 on a hillside rock outcropping. Subsequent additions were built onto the side of the subject property first in the 1930s and then in the 1950s. The first addition, in the 1930s, was constructed on rock ledge and a crawl space. The later addition was built on a full foundation constructed with CMUs. This 1950's addition was built into the hillside providing for walkout access. The later edition also had a finished basement. The entire subject property was renovated in the early 1970s. The subject property possessed three finished living levels, including the finished basement.

During the inspection the IEP observed irregular wall and ceiling surfaces consistent with those exhibited by surfaces that have had past water leakage. Further, gray staining on a basement wall surface exhibiting the characteristics consistent with mold growth was observed. The surfaces and structure at the finished basement also emitted a musty odor.

Subsequent to the inspection the IEP provided the client with a preliminary report. The report recommended testing for fungal contamination. The report also provided clear instructions for engineering controls designed to minimize potential cross-contamination should work be conducted without additional testing.

While the subject property was still vacant, the client engaged a contractor to conduct renovations. She supplied the contractor with the report and directed him to install the engineering controls described in the preliminary report.

In early November the contractor commenced work at the subject property, but failed to install engineering controls described in the report and requested by the client. The client stopped the contractor's work at the job and contacted the IEP in early November requesting the IEP's intervention.

Upon arrival to subject property the IEP observed some of the surfaces suspected to support fungal growth had been removed to the exterior. Prior to the installation of engineering controls at the subject property, the IEP obtained samples for non-viable direct microscopic examination from surfaces and air.

The IEP supervised the installation of engineering controls, including the installation of negative air containment around areas suspected to contain fungal amplification.

The laboratory results for the samples obtained in early November of 2008 indicated marginally elevated levels of fungi existed in the air on the top floor and finished basement area at the time of sampling. The laboratory results from the kitchen area indicated significantly elevated levels of fungi in the air at the time of sampling.

In late January 2009 upon completion of the renovations at the subject property, the client contracted TOMI<sub>ES</sub> to conduct "UV Ozone Deep Cleaning".

Approximately 36 hours after the completion of the UV Ozone Deep Cleaning the IEP return to the subject property to obtain samples for non-viable direct microscopic examination from surfaces and air. The samples were obtained utilizing the same pumps, the same type of media, and from the same locations as the previous samples at the subject property.

**Finding:**

The laboratory results for the samples obtained in late January of 2009 at the subject property indicated a dramatic reduction in the concentrations of fungi in the air on the top floor, finished basement area, and from the kitchen at the time of sampling.

Pre UV Ozone Deep Cleaning sampling of air at the kitchen contained 1440 spores of *Chaetomium* per cubic meter of air, 7253 spores of *Penicillium/Aspergillus*-like fungi per cubic meter of air, and 160 spores of *Stachybotrys* per cubic meter of air. These levels represented concentrations that were significantly higher than the control sample results used for comparison.

Post UV Ozone Deep Cleaning sampling of air at the kitchen contained no detectable concentration for spores of *Chaetomium* per cubic meter of air, 373 spores of *Penicillium/Aspergillus*-like fungi per cubic meter of air, and no detectable concentration for spores of *Stachybotrys* per cubic meter of air.

**Conclusion:**

UV Ozone Deep Cleaning can be an effective disinfectant, useful for the removal of fungal contamination in air.

**National Indoor Environment Testing Center Evaluation Report:**

Subject: The effectiveness of the TOMI<sub>ES</sub> UV Ozone treatment on contaminants in indoor air. National Indoor Environment Testing Center - (China).

National Indoor Environment Testing Center (China) and Shanghai Buqing Building Tech. Development Co., Ltd. have been requested by TOMI<sub>ES</sub> to evaluate the effectiveness of the OZONE treatment on indoor air contaminants (formaldehyde, benzene and TVOC). As all of the parties have signed the service agreement and the evaluation plan, NIETC started to perform the study. Hereafter shows the details of the study.

**1. Objective**

Evaluating the effectiveness of the TOMI<sub>ES</sub> OZONE treatment on indoor air contaminants (formaldehyde, benzene and TVOC).

**2. Documents and standards used in evaluation**

- a. Service Agreement;
- b. National Standard GB 50325-2001, *Code for Indoor Environmental Pollution Control of Civil Building Engineering*.

**3. Devices and equipments used in the study**

- a. An Aeroqual 500 ozone detector;

- b. A GSIIIB automatic air sampler;
- c. A DYM3 aneroid barometer;
- d. A CP 3420 Gas Chromatograph;
- e. OST-14-9 ozone generator.

#### 4. Methodology

- A. A room without any decoration in a civil building was chosen to be the testing room, which is as the condition as those the TOMI<sub>ES</sub> OZONE treatment always treat.
- B. The evaluation of the decontaminating efficiency of the TOMI<sub>ES</sub> UV OZONE treatment on formaldehyde and TVOC in the indoor air.
  - a. Spread a certain mass of contaminant in the air in the testing room and seal all openings. Measure the concentration of the contaminant in the testing room on schedule and draw a time dependent curve of the concentration of certain contaminant. Then unseal all openings of the room and clean it up. This step is to determine the absorption and assimilation of the contaminant under normal condition.
  - b. Spread the same mass of contaminant in the air in the testing room and seal all openings. Start the TOMI<sub>ES</sub> Ozone Generator, measure the concentration of the contaminant in the testing room on schedule and draw a time dependent curve of the

#### Conclusion

Based on the analysis of the results, the NIETC lab has drawn a conclusion depicted hereinafter:

**The max decontaminating efficiency of the TOMI<sub>ES</sub> UV OZONE treatment on formaldehyde in indoor air is 81.6%, and the average efficiency is 71.4%; The max decontaminating efficiency of the TOMI<sub>ES</sub> UV OZONE treatment on TVOC in indoor air is 98.12%, and the average efficiency is 91.44%; The max decontaminating efficiency of the TOMI<sub>ES</sub> UV OZONE treatment on benzene in indoor air is 99.18%, and the average efficiency is 82.83%.**

#### Results

- A. The efficiency of the TOMI<sub>ES</sub> UV Ozone treatment on formaldehyde in indoor air. After 22 hours of UV Ozone treatment, the formaldehyde concentration was < 1 mg/ml.
- B. The efficiency of the TOMI<sub>ES</sub> UV Ozone treatment on TVOC concentration in indoor air. Time dependent curve showed after 23 hours of UV Ozone Treatment a TVOC concentration of nearly 0 mg/ml.

## UV OZONE USED TO ELIMINATE CIGAR SMELL IN BEVERLY HILLS, CA RESTAURANT

Via Alloro, an Italian Restaurant on Canon Drive in Beverly Hills, CA and TOMI Environmental Solutions (TOMI<sub>ES</sub>), have joined to announce a tried-and-true technology in air remediation to eliminate cigar smoke odor.

Upstairs of the restaurant is The Grand Havana Room cigar club, a fixture in Beverly Hills for the past 14 years. During the course of Grand Havana's existence, there have been a number of restaurants which have opened and then closed due to the cigar smoke odor. With the inception of their new restaurant, Giacomino and Tanino Drago approached TOMI<sub>ES</sub>. They had heard that TOMI<sub>ES</sub> had the technology to remove cigar smoke odor which emanated from the club, into the unoccupied crawl space, elevator, and multiple openings to the restaurant below.

Cigar smoke is made up of carbon/sulfur molecules of which ozone will attach to and break them down, eliminating the odors and contaminants in the air.

According to the Dragos, "The natural food smells emanating from the kitchen, and throughout the restaurant are remarkable. The breads smell delicious, and the mushrooms smell divine. It definitely makes for an enjoyable dining experience for our customers."

In addition to its proprietary ultraviolet generators deployed to remove the cigar smoke odor, TOMI<sub>ES</sub> also suggested that UVGI "Terminator" lamps, with ozone, be installed in the HVAC system. This will enhance the clean air environment; at the same time eliminate bacteria, mold spores, allergens, and inactivate viruses. The addition of these lamps represents a total maintenance program to ensure a consistently clean environment.

### **TOMI<sub>ES</sub> Treats Xaverian High School to Inactivate Swine Flu and other contaminants within Its Indoor Environments.**

TOMI Environmental Solution announced the completion of a UV Ozone Deep Cleaning treatment of Xaverian High School with a student body of 1400 located in Brooklyn, New York. The Ozone treatment inactivated contaminants including Swine Flu "H1N1" along with inactivating viruses.

Dr. Halden Shane, TOMIES's CEO, commented, "We are confident that Xaverian High School chose our company to treat their school because we are the leading company in indoor environmental air remediation and feel that TOMI<sub>ES</sub> Methodology in treatment will become a standard for thousands of schools nationwide. It is well documented that polluted indoor environments hamper students' ability to concentrate, perform up to their potential and triggers asthma and many other health-related illnesses. Our clean ozone system delivers an effective solution to providing a healthy environment for children."

Principal of Xaverian High School, Mr. Robert Alesi, stated, "We decided to utilize TOMI<sub>ES</sub> service so our students and faculty could be assured that they are breathing the cleanest air possible in our gymnasium and sports facilities. We took our lead from Senator Marty Golden

whose leadership in helping to keep buildings in Brooklyn green and clean is to be commended.”

New York State Senator Martin J. Golden stated, “I thank TOMI<sub>ES</sub> for bringing their service to Xaverian High School as part of our commitment to ensuring our students are learning in a safe environment, and enabling us to remove the uncertainty that has prevailed in schools across the country under the cloud of 'swine flu'. This service will go a long way in making sure that our schools and businesses are the cleanest of environments. I thank Xaverian High School for their leadership efforts in the community for having this service at the school.”

Mr. Dennis Canale, the school’s Building Manager, stated, “In light of the recent swine flu outbreaks we felt that a deep indoor air remediation of our air ducts and rooms in the sub-basement would keep Xaverian staff and students safe from potential contamination issues.”

### Surface Germicidal Effects of Ozone for Microorganisms

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#### Abstract

In this study the influences of microorganism species, relative humidity, and ozone dosage on ozone surface disinfection were evaluated. Bacterial and fungal cultures were spread on agar plates and exposed to ozone. The selected microorganisms included *Escherichia coli*, *Bacillus subtilis*, *Candida famata*, and *Penicillium citrinum*. Results showed that microorganism survival fraction and ozone dosage (ozone concentration times exposure time) have an exponential relationship. Results also indicated that *E. coli* was the most sensitive organism to ozone exposure. *E. coli* required only very low ozone doses of 2-2.5 and 3.5-4 mg to obtain 50 and 80% inactivation, respectively. In addition, *P. citrinum* was more resistant than *E. coli* and required ozone doses of 40-60 and 60-120 mg to obtain 50 and 80% inactivation. In addition, spores of *B. subtilis* were observed to be the most resistant organism, requiring ozone doses of 40-75 and 145-150 mg to obtain 50 and 80% inactivation. Yeast was less resistant than *P. citrinum* and *B. subtilis*, requiring ozone doses of 10 and 15-19 mg to obtain 50 and 80% inactivation. It was clearly indicated that the ozone dose differences for 80% microorganism inactivation could be as high as 40 times between *B. subtilis* and *E. coli*. Ozone surface germicidal efficiency increased as relative humidity increased, which could be related to more radicals generated from ozone reaction with more water vapor at higher relative humidity. It was concluded that ozone should be highly effective and provide a reliable safety factor in treating contaminated surface. In addition, workers might need to wear suitable respiratory protection at high ozone level operation.

## **OZONE FOR AIR AND MOLD TREATMENT --**

### **A VERY MISUNDERSTOOD ALLY**

**Rip G. Rice, Ph.D.**

**OZONE** – The word instantly conjures up a number of negative thoughts. “The ozone layer is being destroyed and that has affected spray can products”. “Ozone is air pollution. TV weather people cite ozone as the culprit in the ambient air we breathe.” “Ozone is bad to breathe.” “EPA says ozone is good up high but bad nearby”, etc. Now some companies are saying that ozone is good for cleansing air and destroying molds in contaminated homes, apartments, office buildings, and the like. What’s going on?

Hark back to the end of World War I. Chlorine gas had been used to kill soldiers on the battlefields. Not only is chlorine poisonous and heavier than air (so that it could be applied from an airplane and slowly sink to ground level to kill troops and civilians as well). But chlorine had been used since prior to WW-I to treat drinking water. Cholera, typhoid, and other dreaded plague-causing disease organisms were being eliminated in public drinking water supplies, saving millions of lives the world over. People of the post World War I era had the same negative reactions to the beneficial uses of chlorine as people of our time now have when introduced to the beneficial uses of ozone.

Since World War I, chlorine has provided consumers with many can’t-do-without products, such as bleached paper pulp, synthetic dyestuffs, textiles, petroleum products, medicines, antiseptics, insecticides, solvents, paints, plastics (PVC films and piping). All these from something that was used to kill people during a war. How has this been possible?

Now examine the properties of ozone. It is also a gas, but is made naturally (the ozone layer and as a component of smog). Ozone also can be man-made, with oxygen as its major starting material. This gas is unstable, however, and quickly reverts back to oxygen in a short time (a few hours in air, a few seconds in aqueous solutions). Consequently, there is no possibility to generate ozone at a central manufacturing plant, package, store, and ship to a point of use. Instead, ozone must be generated and applied where it is used.

As with chlorine, the trick to the safe and successful commercial uses of ozone is to understand its properties, recognize those that are dangerous, and then develop techniques to handle the gas so that it can be applied safely.

In the early 1900s ozone began to be used commercially for drinking water treatment (in France), for odor control in German meat packing houses, and for mold control in German brewery cellars (Horváth et al., 1985; Kuprianoff, 1953). Concentrations of ozone applied for these purposes were rather high (several thousand ppm) for drinking water disinfection) and rather low (0.1 to 10 ppm) for odor and mold control. The benefits of ozone for these applications were readily apparent, and it was quickly recognized that this new gas was both a powerful disinfectant and simultaneously a powerful oxidizing agent.

## **OZONE AND ITS MANY APPLICATIONS**

Despite this developing negative attitude toward ozone, vendors of ozone equipment, during the early times and still today, usually are small companies with technical expertise in producing ozone, but are lacking the resources necessary to conduct the R&D necessary to understand the product they are marketing. However, their diligence and persistence continued to show that ozone can provide numerous advantages in many applications -- water and wastewater treatment, swimming pool water treatment, odor control, preservation of foods, treatment of contaminated buildings and its air, etc.

In addition to purifying drinking water commercially, ozone is being used commercially today to treat bottled water, cooling towers, swimming pools and spas, in the production of chemicals, pharmaceuticals, marine aquaria, soft drink water treatment, wastewater treatment, cosmetics manufacture, electronics, kaolin bleaching, fish farming, food processing and packaging, food storage, grain treatment, ice making machines, commercial laundries, etching of plastics, bleaching of paper pulps, depuration of shellfish, soil remediation, water parks, etc. Ozone also is used commercially to treat air (to remove odors and in air conditioning ducts) and to destroy molds.

How can such a dangerous material be used successfully and safely? The answer is the same as for chlorine – by learning how to handle it appropriately and safely for its intended applications.

Here are the basic principles for using ozone in some air treatment applications.

1. Understand that breathing ozone is a no-no. Three agencies of the U.S. Government have set strict standards on the concentrations of ozone that can be safely tolerated by human beings.

OSHA -- 0.08 ppm (time-weighted average over an 8-hr day, 5-days/week). This is a standard established for healthy workers in commercial and industrial plants.

U.S. EPA – 0.08 ppm. This is a standard established for ambient air that we humans breathe whenever we are outside of our homes.

FDA – 0.05 ppm. This standard is established for people confined to a room and who would be exposed 24 hrs/day, 7 days/week, and 365 days/yr.

In addition, the ASHRAE (American Society of Heating, Refrigeration and Air conditioning Engineers) has adopted a guidance for ozone used to treat air conditioning ducting. The concentration of ozone exiting any AC duct must not exceed 0.05 ppm (the FDA standard).

2. For most applications, the concentration of ozone necessary to be effective far exceeds the maximum human exposure levels established by the above government agencies. This means that people (and pets, many types of plants, etc.) should not be present when indoor air is being treated by ozone.

3. The inescapable conclusion is that ozone can be applied and used successfully, ***but only in the absence of humans, pets, and ozone-sensitive plants and items.***

As will be described later, a safer approach to ozone treatment of indoor contaminated air is to remove people, pets, sensitive plants, etc., from the contaminated area, add sufficient ozone to destroy the contaminants rapidly, and then exhaust the ozone-treated indoor area, replacing the treated air with fresh air.

### ***OZONE AND PHOTOCHEMICAL SMOG***

In smog, the irritating effects to humans are caused more by the organic and organic-nitrogen constituents than by the ozone itself. However, since the gas phase analysis of ozone by modern instruments is so accurate and so simple, compared to the analysis of other photochemical smog constituents, and since the concentration of ozone is proportional to the other constituents of photochemical smog, the U.S. EPA has specified that the total photochemical smog be reported as ozone by monitoring stations all over the USA -- a practice which has been adopted in many other areas of the world.

Thus, when citizens turn on the TV in the evening and hear that "the air pollution level today is in the danger level for ozone", the negative perception of ozone enlarges.

### ***FDA's POSITION ON OZONE FOR INDOOR AIR TREATMENT***

The Office of Radiological and Medical Devices Division of the U.S. Food and Drug Administration in the mid-1970s ruled that ozone generators marketed with a pesticidal claim ("ozone in the air will kill microorganisms" or "ozone will make the air safe to breathe") to be operated in an enclosed room or building where people can breathe that ozone, are misbranded. FDA's reasoning was based on published, peer reviewed scientific studies showing that at an ozone level in the room air above 0.05 ppm, ozone indeed does a credible job of disinfecting microorganisms. However, above 0.05 ppm, ozone is also toxic to people who breathe ozone-containing air 24 hours/day, 7-days per week, 365 days per year.

The FDA's position continues to fuel the negative impressions of ozone.

### ***EPA's POSITION ON INDOOR AIR TREATMENT WITH OZONE***

The Indoor Air Quality Division of the U.S. EPA is concerned with ozone generators for installation in homes and buildings wherein people can breathe the ozone. They have produced a position paper that is readily available for downloading on the EPA web-site: (<http://www.epa.gov/iaq/pubs/ozonegen.html>). EPA's position paper assumes that ozone will be applied indiscriminately by the user and ozone will be breathed, thus continuing the negative impression of ozone.

Buried in EPA's position paper is a paragraph addressing the question, "Can ozone be used in unoccupied spaces?"

"High concentrations of ozone in air, **when people are not present**, are sometimes used to help decontaminate an unoccupied space from certain chemical or biological contaminants or odors

(e.g., fire restoration). However, little is known about the chemical by-products left behind by these processes”. . . “While high concentrations of ozone in air may sometimes be appropriate in these circumstances, **conditions should be sufficiently controlled to insure that no person or pet becomes exposed**” (emphasis added by author).

Later in this article, we will describe a commercial ozonation servicing technology that lives within the EPA's position of the preceding paragraph.

### **HEALTH CANADA'S POSITION ON AIR TREATMENT WITH OZONE**

Health Canada ([http://www.hc-sc.ca/english/protection/warnings/1999/99\\_62e.htm](http://www.hc-sc.ca/english/protection/warnings/1999/99_62e.htm)) has adopted a position with respect to the treatment of indoor air with ozone that is similar, if not identical, to that of the U.S. EPA – ozone at levels high enough to treat the air are also toxic to humans and pets. However, included in the Health Canada warning about ozone generators for household use is the following paragraph:

***“This warning does not apply to ozone generators designed for use in industrial applications such as fire damage restoration and water purification where occupants are not normally present.*** (Emphasis added by author) Any beneficial application using ozone requires extremely high levels of ozone to be effective and this is not safe for human exposure.

Health Canada has recognized that there **ARE** responsible, ozone-knowledgeable vendors of ozone equipment, used for treating indoor air and indoor environments, who are using ozone to provide benefits to consumers without endangering their health.

### ***Generation of Ozone by Man***

Commercially, three methods are employed to generate ozone – corona discharge, ultraviolet (UV) radiation, and electrolysis of water. Only the first two methods are used currently for generating ozone for air treatment.

### ***Ozone Generation by Corona Discharge (CD)***

By this technique, an oxygen-containing gas (air, oxygen, or mixtures thereof) is passed between two electrodes through which electrical energy is applied. Oxygen molecules are ruptured, and the oxygen fragments can combine with non-dissociated oxygen molecules to produce ozone.

If ozone is generated under uncontrolled conditions in ambient air containing moisture by corona discharge techniques, some byproducts will include nitrogen oxides. These arise by the simultaneous dissociation of some nitrogen molecules, the fragments of which can combine with oxygen molecules.

In the presence of moisture, these nitrogen oxides can produce nitric acid, a very corrosive liquid. With air dried to currently recommended dew points (-75°C), however, formation of nitrogen oxides is reduced to insignificant levels, thus eliminating the formation of nitric acid.

On the other hand, the costs to dry the feed-gas air are significant, and many small, new-to-ozone

vendors choose not to offer air drying equipment to a potential customer so as to be able to underbid his (more ozone-educated) competition and win the sale. This marketing approach has resulted in many equipment failures, and continues the negative view about ozone.

### ***Ozone Generation by UV Radiation***

This method of generating ozone involves passing ambient air through UV radiation, at which time, some oxygen molecules (but NOT the nitrogen molecules) are ruptured and ozone is formed when these oxygen fragments find and associate with oxygen molecules.

UV bulbs are manufactured using different materials to produce different wavelengths. The germicidal UV bulb produces radiation of primarily 254 nm. At this wavelength, very little ozone is produced. In fact, ozone is destroyed rapidly upon exposure to UV at this wavelength.

When UV bulbs are manufactured to produce UV radiation at primarily 185 nm, then considerable ozone is produced, sufficient to treat considerable volumes of contaminated indoor air at ozone concentrations sufficient to destroy odors, smoke, and molds, if allowed sufficient time of contact. An additional advantage is that there is no need to dry the feed gas air, and no nitrogen oxides are formed by this method of ozone generation.

Vendors of "air ionizers" have long ago recognized that their devices produce ozone. Yet their marketing claims do not mention the word "ozone", because of the public's negative perception and because using the word would invite unwanted scrutiny by regulators (EPA, FDA, etc.). But when a person that knows what ozone smells like enters a room containing an "air ionizer", a distinct odor of ozone is recognized instantly.

### ***Treatment of Indoor Air with UV Ozone***

It is clear from the statements of the EPA, Health Canada, and many other health-oriented agencies and associations, that the many oxidative and disinfection benefits of ozone can be obtained only if levels that far exceed regulatory standards are applied. In turn, this means that humans, pets, and ozone-sensitive materials (plants, art, rubber items, etc.) must not be present when sufficiently high levels of ozone are applied to solve an indoor air treatment problem.

Another critical consideration in treatment of indoor air with ozone is the way ozone is generated. If the corona discharge technique is used, ambient air is used to feed the ozone generator, the air should be dried to a maximum dew point of -65°C (and preferably lower) in order to prevent the simultaneous formation of nitrogen oxides. These oxides can combine with moisture in the ambient air to produce nitric acid, which is a very corrosive acid that will produce unwanted side effects during treatment.

When ozone is generated by UV radiation using UV lamps producing significant levels of 185 nm wavelength radiation, then sufficient gas phase concentrations of ozone (without nitrogen oxide and thus nitric acid formation) are produced to raise the level of indoor ozone to 9-12 ppm and to maintain this concentration until ozone has completed its intended work – deodorizing, oxidation,

disinfection, etc. During this period of ozonation, the indoor facility is sealed, after removal of humans, pets, and ozone-sensitive contents. Following ozone treatment, the facility is opened and fans exhaust the ozone-treated air and simultaneously draws clean air into the treated space.

When a mold-contaminated room is treated with ozone in this manner and then vacuumed with a HEPA (High Efficiency Particulate Air) filter system, the treated indoor space is decontaminated. A good example of this process comes from a public company in the United States, TOMI Environmental Solutions and its licensees, who use UV, nitric oxide-free ozone generators and follow this indoor air treatment procedure with great success.

## ***SUMMARY***

The many advantages of ozone derive from it being both the most powerful disinfectant and chemical oxidant available to mankind on a commercial scale. Prior to adoption of ozone in many industrial applications, the same could be said of chlorine.

Responsible application of ozone to treat molds and water damaged homes, buildings, etc., involves removing people, pets, and ozone-sensitive plants and other items from the space(s) to be treated, then applying sufficient ozone to accomplish the intended purpose(s). After treatment, excess ozone is removed from the premises before allowing return of the people, pets, plants, etc.

Whether the continued development of beneficial uses for ozone will someday overshadow the public perception of the negative aspects of the word "ozone" is an eventuality to be desired. The International Ozone Association, a scientific and educational organization in its 31st year of spreading facts about ozone and not myths, is doing yeoman work to point out the benefits of ozone when used properly ([www.int-ozone-assoc.org](http://www.int-ozone-assoc.org)). Some science editors have begun to write about ozone in a positive vein, rather than negatively, particularly when they are presented with all of the facts and not with unsupported claims. It would appear however, that reversal of the initial negative public reaction upon hearing or seeing the word "ozone" is still a long way off.

## ***REFERENCES***

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RGR, Feb. 22, 2005.