The Application of Ozone Technology for Public Health and Industry

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Executive Summary

In this paper we will be reviewing some of the many applications of ozone technology for use in industry and public health. When used properly and safely ozone technology can be a cheap and effective tool for eliminating many unwanted odors and indoor air pollutants. Some of the most successful applications of ozone may be in manufacturing industries such as food, beverage, pharmaceutical, healthcare, and the hospitality. In the area of public health, ozone technology may be a potential source for reducing the risk of infection both in the home and in health care facilities.

The purpose of this paper is to give an accurate representation of the technology for use in the above mentioned areas as well as dispel misconceptions about the ozone. Ozone has also been a controversial topic in the past as a result of eccentric claims about its possible uses. In order for consumers to make well informed decisions about this science we will be reviewing the advantages, as well its limitations. We will describe many of the areas where this technology can help to improve product quality in such applications as food and water processing, as well as help to make environments safer.

This paper is sponsored by EcoQuest International a leader in the development of science and technology related to indoor air and water purification systems. These systems are designed using the latest ozone and ultraviolet light technologies available. The mission of EcoQuest International is to help people live better. EcoQuest does this through the distribution of their products for use in homes, schools, and businesses.

There are numerous environmental issues facing the public health and industry here in the U.S., as well as the rest of the world. Emerging and new infectious diseases have been a growing concern since the early 1980's (Nelson, 2004). Food safety and security has been an ongoing battle with outbreaks occurring routinely. Threat of biological or chemical attacks to our air, food, and water has also heightened since September 11, 2001.

Population growth is possibly the most important factor resulting in overcrowding and marginal sanitary conditions being associated with the increase in infectious disease (Nelson et al., 2004). An aging population of baby boomers will require nursing homes and health care facilities to take on even larger numbers of patients. Schools and daycares are also seeing more consolidation resulting in overloading of facilities. In parts of Asia overcrowding of persons with domestic birds has opened up the world to the threat of epidemic from severe acute respiratory syndrome (SARS) and from H5N1 influenza (Avian Flu) (Orent, 2005).

In the following sections applications for ozone use for possibly reducing infections in health care, hospitality industry, travel industry, clean room, medical device handling, and livestock production, will be reviewed. Also, many successful applications of ozone in food, beverage, water and wastewater treatments will be detailed. Advantages and disadvantages about ozone will be discussed along with misconceptions about the technology.

Introduction to Ozone Technology

Ozone occurs naturally in the atmosphere and serves several very important functions in our existence here of earth. A protective layer of ozone is present 6 to 30 miles above the earth's surface at a concentration of approximately 10 ppm (parts per million). This ozone layer helps protect the earth's surface from harmful ultraviolet radiation and prevents heat loss from the earth's surface. Ozone is also generated during lighting, which is why the air smells so fresh after a thunderstorm.

Ozone has a tremendous ability to oxidize substances. It's thousands of times faster than chlorine and disinfects water three to four times more effectively. Ozone seeks to oxidize everything. Human exposure to high levels of ozone will irritate lungs, eyes, and skin. Many cities post ozone levels because the sun's UV light waves strike oxides of nitrogen from auto exhaust and factory emissions, converting them to ozone. Some researchers believe that ozone will actually help to clean up pollution, while many others feel that the negative health effects outweigh its benefits (Fink, 1994).

Ozone is a very strong oxidizer. As it oxidizes a substance ozone will literally destroy the substance's molecule. It can oxidize organic substances such as bacteria and mildew, sterilize the air, and destroy odors and toxic fumes. Ozone has been used by industry for many years and in many different types of applications such as odor control, water purification, and as a disinfectant (Mork, 1993). Recent government approval of ozone for use with foods and food contact surfaces has opened up the door to many more exciting possibilities for this technology.

Indoor Air Quality

It is estimated that people spend approximately 90 percent of their time indoors (U.S. EPA, 1993). The health risks for most people may be greater due to exposure to bad indoor air quality than outdoors. People who are exposed to indoor pollution for the longest periods of time are often those most susceptible to the adverse effects of indoor air pollution. Sometimes indoor air problems are a result of poor building design or occupant activities. Health effects related to where individuals live or work, such as homes, apartments, offices, schools and nurseries, have become an escalating public health issue.

According to the United States Environmental Protection Agency (U.S. EPA, 1993) indoor air pollution is now considered be one of the biggest environmental health issues in this country. Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems. Poor ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home.

Sources for indoor air pollution are numerous and include such things as burning of wood and tobacco products; building materials and furnishings, carpets, and furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; outdoor sources such as pesticides, and outdoor air pollution; indoor animals and pests such as cats, dogs, rodents, and dust mites). All of these substances produce allergens that contribute to the incidence of diseases such as asthma (Bahnfeleth & Kowalski, 2005).

The importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant (Tilton, 2003). Some sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources, related to activities carried out in the home, release pollutants intermittently. These include smoking, the use of unvented or malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaners, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in housekeeping. High pollutant concentrations can remain in the air for long periods after some of these activities.

Sick Building Syndrome

Sick-building-syndrome is any building that causes health problems such as allergies, skin rash, respiratory ailments, loss of concentration, and headaches. Most illnesses are the result of poor ventilation (Bahnfleth et al., 2005). When ducts aren't cleaned regularly, they can release dust and fibers. Energy efficiency has limited the amount of fresh air circulated through the buildings, you still need.

Microbial contamination of indoor air represents a major public health problem and source of sick-building-syndrome. Mold for example, is a major factor in sick-building-syndrome becoming an ever increasing concern to many home owners and businesses. In addition to being unattractive to see and smell, mold also gives off spores and mycotoxins that cause irritation, allergic reactions, or disease in immune-compromised individuals (Bahnfleth et al., 2005).

Prevention of Indoor Air Pollution: Ventilation and Air Cleaners

The U.S. EPA (1990) lists three main strategies for reducing indoor air pollutants: source control, ventilation, and air cleaning. Source control is considered the most effective and eliminates the sources of pollutants or reduces their emissions. Regrettably, not all pollutant sources can be identified and practically eliminated or reduced.

Ventilation is effective because it brings outside air indoors. This is typically achieved by opening windows and doors, by turning on exhaust fans, or through the use of mechanical ventilation systems (EPA, 1993). Limitation to the use of ventilation centers around the costs for heating or cooling incoming air, and outdoor air may also contain adverse levels of contaminants (Bahnfleth et al., 2005). In the following paragraphs the most common air cleaning systems, filters, ionizers, and Ultra Violet (UV) light, will be discussed.

One of the most common filtering methods is HEPA filtration. HEPA stands for high-efficiency particulate arrestance. HEPA filters use a powerful blower to force the air through a very tight membrane to achieve high-efficiency particulate filtration. The biggest advantage of the HEPA filters is that they are very efficient in the filtering of air that passes through the filter and can filter to 0.03 micron. The drawback is that they require routine filter changes. The filter can also act as a breeding ground for bacteria, mold, and fungus. They do not remove odors, gases, pesticides, viruses, and many bacteria. They reduce airflow due to the tight pores of the filter. They are generally not used in central systems, and are sold as stand-alone units only (Fink, 1998). When air ventilation is restricted due to building design or for energy saving reasons the use of an air cleaning system is your main choice to for treating re-circulated air (Bahnfleth et al., 2005).

Carbon filters are another method of filtration, incorporating the use of carbon impregnated filter fabric or granulated carbon. These filters usually have a foam or fabric filter to hold the media. Carbon has the unique capability of acting as a physical filter trapping particulate, and on a chemical basis by reacting with some odors and some of the heavy gases. A notable advantage of the carbon filter is that it absorbs odor, absorbs some gases, and filters particulate. Some major disadvantages are the method requires frequent changes, acts as a breeding ground for microorganisms, can easily become blinded and ceases functioning.

Fiber or open-cell foam filters rely on the air passing through a matrix of foam cells or fibers of fiberglass, wire, plastic, or doth. Typically, these filters only stop medium to large particulate. The low cost is probably the main advantage to this filtration method (Fink, 1998). The disadvantages of the system are they only filter the air that passes through the filter and the particle buildup can act as a breeding ground for bacteria.

Electrostatic precipitators (Ionizers) have been used by industry for many years to clean up smoke stack emission of particulate. They operate by electrically charging a field between metal plates. The air is charged with an electrical charge similar to static electricity. The charged particulates collect and coagulate on a second set of charged plates where they build up and fall to a collection tray. Advantages include effectiveness at removing smoke from the air that passes through the filter. They do not reduce airflow as most other filters do. They can be installed in central units or in each room. The disadvantage is that they require frequent cleaning and they only filter the air that passes through the filter. The particle buildup can act as a breeding ground for bacteria.

Negative ion generators have been used by industry for years to remove particulates from the air and to neutralize the effects of excess positive ions. Negative ions are produced electrically and travel through the air until they attract airborne particulate, and coagulate the particulates until they are too heavy to drift and settle to the floor. The negative ion generators are effective at removing smoke from the air. They travel throughout the entire room and purge all the air of particulate, not just the air that passes through a filter. The down side to their use is that they drop the particulates to the ground. It is best that they be in each room, as many believe the ions cannot effectively travel through HVAC ducts.

Ultraviolet (UV) light rays have been used as a sanitizer by the medical profession for years. UV light can also sanitize air that is passed directly in its path. UV light can destroy bacteria, fungus, molds, and some gases. It does not reduce airflow. Can be installed in a central or individual room unit. The disadvantage of UV light is that is has no effect on particulate, needs direct close contact with a calculated exposure time. UV light rays must be shielded from human exposure.

Ozone Technology for Indoor Air

Ozone used for aerial treatments is typically conducted in gaseous form. In this state the ozone is colorless with a characteristic odor. Ozone consists of an oxygen molecule containing three atoms instead of two, like the oxygen we breathe. The extra atom of ozone is known as a loose radical that looks for organics to attach to and thereby oxidize. Ozone is known as a friendly oxidizer, due to the fact that it reverts back to oxygen after oxidation occurs. Ozone is an oxidizing gas that travels throughout the room and oxidizes all organics. Ozone can neutralize most odors and certain gases. Ozone destroys microorganisms and does not reduce airflow. Ozone units can be installed in central units or in each room. Ozone usage comes with safe usage limits and exposure levels must be controlled to meet government guidelines.

Ozone has been used for many years by professional cleaning and disaster restoration companies. These professionals utilize ozone to disinfect sick houses, destroy mold, mildew, fungi, or smoke from fire damage. Research has found that ozone levels of less then 9 ppm are necessary for sick buildings or profession disinfection (Khurana, 2003). These low level ozone applications have been found to be effective at reducing populations of bacteria, fungus, and viruses.

The issue of safety must always be addressed when using ozone technology for use indoors with human exposure. A study by Boeniger (1995), found that ozone air cleaners are a potential health risk if used at high levels indoors. Current ozone technology manufacturers seem well aware of this health risk and have worked to improve the science to make ozone safer for use indoors. For example, a photo-hydro-ionization (PHI) cell developed by RGF Environmental Group, Inc has been designed to not exceed the recommended Federal safety limits for ozone (0.04 ppm) in an occupied room. In the following sections on odor control and sick building syndrome we will discuss ozone applications for improving indoor air quality in more detail.

Air cleaning is a critical component for ventilation. However, the use of air cleaning alone cannot assure adequate air quality, particularly where significant sources of air pollutants are present and ventilation is inadequate. As mentioned earlier sources of air pollution need to be eliminated to control indoor air quality. Since ozone works to oxidize the air as well as a surface area it comes in contact, ozone technology is well suited for this application (Fink, 1994).

A review of all the available air-purification technologies clearly shows that there is not one simple, all-purpose technology. Designers and maintenance technicians must decide what level of filtration is needed, and what pollutants are in the air. Once these two key questions are answered, an air-purification program can be developed using a combination of appropriate technologies that fits the budget.

Unwanted Odors

Odor problems originate from numerous sources; bacteria, molds, tobacco smoking, fumes from chemicals, cooking, fireplaces, and pets. Odors can be big problems when they are affixed to clothing, furniture fabrics, or carpets. Mold and fungus contamination are another major source of unpleasant odors. Damp spots around humidifiers, attics and crawl spaces under homes, basements, bathrooms, house plants, air ducts, damp ceilings and walls, wet carpets and windows are all sources for contamination. Mold creates a musty, stale odor which can be both an annoyance and a health issue to those suffering from allergies or asthma. Condensation from steam and poor ventilation is the biggest cause of mold in bathrooms and around clothes dryers or stoves when they are not properly vented to the outside.

Odor removal consists of masking the odor with a more pleasant or less offensive odor or removing the odor. Filtering systems are common for use in removing of cigarette or pet odors. However, air filters require the air in the room to be pulled through the filter. Air filters also cannot remove odors imbedded into clothing, furniture fabrics, and rugs. Masking the unpleasant odor with a more pleasant odor is a common practice but is only a short term solution to the problem.

Ozone technology is another available technology for odor removal. Airborne ozone has been used effectively in removing odors from previously occupied homes, including odors from pets and molds (Balnfelth et al., 2005). Ozone has been identified as giving a scent that is similar to freshly laundered bed sheets. It is still debated by some researchers as to how ozone works on odors, by masking them, eliminating them, or both. However, the effectiveness of ozone at eliminating unwanted odors is well documented (Purofirst, 2001). The main theory behind the ability for ozone to remove odors is quit simple. When ozone comes in contact with organic compounds or bacteria, the extra atom of oxygen destroys the contaminant by oxidation. Ozone decomposes to oxygen after being used so no harmful by-products result.

Ozone will neutralize virtually all organic odors, specifically those that contain carbon as their base element. This will include all the bacteria and fungus groups as well as smoke, decay, and cooking odors. Ozone is not as effective on inorganic odors like ammonia, phosphates, nitrates, sulfates, chlorides, etc. The U.S. EPA states that there is not yet enough data available to determine which chemicals ozone is effective against. One odorous chemical compound which ozone has proven to be effective against is acrolein. Acrolein, is one of the many odorous and irritating chemicals found in secondhand tobacco smoke will break down when it comes in contact with ozone (U.S.EPA, 1998).

Ozone is a toxic gas. However, it can be used safely when deployed by specialized generators under proper considerations. The odor of ozone is detectable by most people at a level of 0.003 - 0.015 ppm and become intolerable to most people at 0.15 ppm. The general consensus is that when you can smell ozone gas it's time to evacuate the area of life forms (Purofirst, 2001).

Restoration of homes or buildings damaged by smoke has been a successful application of ozone. Smoke odor molecules that infiltrate all porous surfaces can be permanently removed by ozone gas. Only ozone will work on the most stubborn of all odor molecules, that being protein (Purofirst, 2001). Odors associated with decaying foods or animals, such as rodents, have long resisted normal chemical deodorizing attempts. Ozone has the potency to neutralize even these contaminants

A huge advantage of ozone over other types of deodorizers is that after it is done working to remove odors it reverts back to normal oxygen within 15 to 30 minutes. However, other safeguards must be observed other than evacuation. Due to its oxidizing nature, ozone attacks and degrades natural latex rubber, thus a laminate like silica should be applied to car and freezer door moldings. Ozone also breaks down and thus oxidizes faster in the presence of moisture. Even high relative humidity can increase its action. Hydrogen Peroxide, mild bleach, forms when ozone is exposed to sufficient moisture, so certain textiles should be removed. A possible disadvantage of ozone for odor control is when it comes in contact with certain carpets. Unpleasant odors may arise that differ from new carpet smell (Potera, 2002). The fumes develop from the oxidation of vegetable-based machining oils found in carpets. The odors, which dissipate relatively quickly, do not cause any acute health effects but may be annoying to some people.

Nosocomial (Health Care) Infections

Impact on Human Health

Nosocomial infections are infections acquired from the hospitals as well as any other health care facility such as nursing homes and health clinics. The importance of nosocomial infections seems to have become better understood only in these past few decades. Nosocomial infections have been a huge burden on the overall population. It is estimated that in the United States that more than two million nosocomial infections occur every year (Yalcin, 2003). As of 1995, nosocomial infections cost $4.5 billion and have contributed to more than 88,000 deaths annually. Adding up to one death every 6 minutes and the rate continues to grow every year (Weinstein, 1998).

It is believed that the majority (80%) of health care infections are caused by the microbial flora that patient bring with them to the health care facility (Tilton, 2003). This micro-flora seems to be opportunistic to the new environment and is able to take advantage of new routes that medical procedures offer. Other nosocomial infections (10% to 20%) develop following contamination found within the health care environment.

Mold is a major contributor of health care infections. The mold *Candida* species for example, is the fourth leading cause of nosocomial blood stream infections in US hospitals (Gudlaugsson et al., 2003). Data has shown that patients who acquire candidemia are likely to die during hospitalization as a result of the infection (Gudlaugsson et al., 2003). According to Gudlaugsson and associates the prevention of health care infections caused by *Candida* species should be a high priority for any health care facility.

Nosocomial infections within the health care facility have multiple sources which promote to the spread of infectious disease. These sources with the health care facility include: advances in health care which often result in new sources for infection, cutbacks in staffing at many health care facilities have placed a greater burden on the medical staff (Chotani et al., 2004). The human factor seems to be one of the biggest concerns with health care workers transmitting infection from patient to patient. Many health professionals believe that the best way to confront this factor is to remove that human factor whenever and whereever possible (Kohn et al, 1999). This may be accomplished through the development of safer invasive devices and health care facilities which are less likely to harbor infection.

Preventing Nosocomial Infections

A successful infection control program can not only help reduce mortality and morbidity rates in hospitals but can also be very cost-effective for health care organizations (Khon et al., 1999). Considering that one third of all nosocomial infections are preventable, prevention and control measures need to be a priority for any health care organization (Tilton, 2003).

To fight infections which occur in health care settings an approach using various integrated prevention measures is considered the most effective (Tilton, 2003). This includes such measures as, good hygiene practices by health care employees, invasive medical devises free from contamination, therapy pool disinfectant program, and continuous disinfecting of rooms and equipment throughout the health care facility. Disinfecting applications at home are also advisable, especially for those who are immune-compromised or will have extended stays in health care facilities. As mentioned earlier, a large number of infections (80%) are brought with the patient to the hospital.

Disinfecting means the use of a chemical procedure to eliminate virtually all recognized pathogenic microorganisms but not necessarily all microbial forms on inanimate objects (Tilton, 2003). Antimicrobials such as iodine, chlorhexidine, 70% isopropyl alcohol solution, and hexachlorophene are frequently used in hospitals and other health care facilities. Chlorhexidine and hexachlorophene are active against many microorganisms but are less effective against Gram-negative bacteria.

Ozone is a powerful, broad-spectrum antimicrobial agent that has been found to be effective against bacteria, fungi, viruses, protozoa, and bacterial and fungal spores (Kim, Yousef, & Chrism, 1999). The anti-microbial activity of ozone is based on its strong oxidizing effect, which causes damage the fatty acids in the cell membrane.

A big problem in control health care infections is that some strains of bacteria can actually build up a resistance to certain chemicals disinfectants (Tilton, 2003). Ozone, on the other hand, kills bacteria within a few seconds by a process known as cell lysing. Ozone molecularly ruptures the cellular membrane, disperses the cell's cytoplasm and makes reactivation impossible. Because of this, microorganisms cannot develop ozone resistant strains; thus eliminating the need to change biocides periodically (Pope et al., 1984). Because of application advantages such as this, ozone technology may fit in well with other disinfectants in a combined strategy to prevent nosocomial infections.

Food and Beverage Industry

The food and beverage industries face a number of issues when it comes to producing a safe, wholesome product. Food pathogens such as *E. coli* 0157:H7, *Salmonella* species, *Listeria moncytogenes*, and *Clostridium bolulinum* have been a growing concern throughout the years. Processors are also concerned about spoilage microorganism which shorten shelf life and cost companies millions every year in spoiled product. Industries impacted include the meat, seafood, poultry, produce, baking, canned foods, dairy, and almost all other segments of the market. The beverage industry must be aware of the water quality they are using for blending and mixing.

The USDA estimates the costs associated with food borne illness to be about $5.5 billion to $22 billion a year. This doesn't include the billions lost every year due to spoiled product, which must be disposed or sold as a lesser valued product. Better disinfection and microbiological control measures are needed in almost every area of the food industry.

Current Trends in Prevention and Control

Chlorine is a common disinfect used in meat processing and is effective and safe when used at proper concentrations. However, chlorine is far less effective than ozone at oxidizing and reacts with meat forming highly toxic and carcinogen compounds called tri-halomethanes (THMs) rendering meats lesser quality products (Cunningham & Lawrence, 1977). THMs were also implicated as carcinogens in developing kidney, bladder, and colon cancers. Chlorine also results in the production of chloroform, carbon tetrachloride, chloromethane besides THMs. On the other hand, ozone does not even leave any trace of residual product upon its oxidative reaction.

Fresh-cut produce is a rapidly growing segment of the food industry reaching sales of $76 billion in 1999 (Kaufman et al., 2000). Outbreaks from food pathogens in this industry have also increased, going from about 4 per year in the 1970's to over 10 per year in the 1990's (CDC, 2005). Ozone and chlorine rinses of produce are two of the most common disinfecting treatments available. Ozone was approved for use as an antimicrobial treatment on produce by the FDA in 2001 and has shown evidence of being an extremely effective application. Studies by Kim et al (1999) found that an ozone rinse of just 1.3 ppm for 5 minutes produced a greater than 99.9% reduction in psychrotrophic and mesophillic bacteria on lettuce.

In June 2001, the FDA approved the use of ozone as a sanitizer for food contact surfaces, as well as for direct application on food products. Up until that time, chlorine was the most widely used sanitizer in the food industry. Ozone may be a better choice for disinfection of surfaces than chlorine. Chlorine is a halogen-based chemical that is corrosive to stainless steel and other metals used to make food- processing equipment. Plus chlorine can be a significant health hazard to workers. When mixed with ammonia or acid cleaners, even in small amounts, a toxic gas can form.

The application of ozone in the flour milling industry has been found to be an affective means of cleaning the grain in the mills cleaning house. A study performed at the Harvest Milling flour mill in Huron, Ohio showed a 75% to 80% reduction in total plate count bacteria in ozone-treated flour compared to conventional treatment with chlorine (Zdrojewski, 2001).

An important advantage of ozone used in food processing is the product can still be called organic. An organic sanitizer must be registered as food contact surface sanitizer with the U. S. Environmental Protection Agency (EPA). Ozone is, plus it has FDA approval as a sanitizer for food contact surfaces, as well as for direct application on food products.

In a recommendation to industry the FDA (2004) stated that "ozone is a substance that can reduce levels of harmful microorganisms, including pathogenic *E. coli* strains and *Cryptosporidium*, in juice. Ozone is approved as a food additive that may be safely used as an antimicrobial agent in the treatment, storage, and processing of certain foods under the conditions of use prescribed in 21 CFR 173.368."

Animal Health and Zoonosis

Sickness and disease can be devastating to any animal population, but the impact on animal health can be extremely costly to farming, ranching, boarding, and breeding operations. Some examples of disease causing infections in livestock include; Infectious Bovine Rhinotracheitis (IBR), a common disease in cattle which affects all age groups of cattle but hardest hit are young feedlot cattle; In swine, respiratory diseases caused by major pathogens such as *Mycoplasm* sp., *Actinobaillus* sp., *Pasteurella* sp., and *Bortadella* sp., are usually highly contagious and can often be fatal; and in poultry, Air-sac disease and Septicaemia result in increased mortality and condemnation rates of flocks.

Serious animal disease issues are not only limited to livestock, but also affect the pet population as well. For example, Kennel Cough is a common ailment in dogs that can be comparable to the common cold in humans. People tend to associate the disease with dogs that have recently been boarded or have participated in large dog shows. Kennel Cough can be caused by a number of viruses as well as bacterial species, often with the disease being caused by a combination of the two types of organisms. Primary among the viruses implicated are Canine Adenovirus type 1 and 2 as well as Canine Parainfluenza virus (De Boer, 2005). Probably the single most important culprit causing Kennel Cough is a bacterium called *Bordatella bronchiseptica*. Any time a dog is even in the near vicinity of an infected dog, the potential increases for infection due to the airborne dispersal of these organisms. The incubation period of Kennel Cough is about 8-10 days, meaning the dog could be harboring the infection 8-10 days before symptoms manifest.

Although there is a vaccine for Kennel Cough currently available, the vaccine alone is not effective in preventing infection. The most likely explanation of this is that there are many strains and mutations of the viral or bacterial strains causing Kennel Cough, making it highly impossible to find the right strain to use in the vaccination. This is a similar issue to the flu shot enigma; each year a vaccine is developed based on which strain(s) are suspected to be most prevalent (De Boear, 2005). Be aware that dogs can still catch Kennel Cough even if the animal has been vaccinated to prevent it.

Maintaining good environmental conditions for animal holding and housing facilities is often a difficult issue to overcome. In most facilities, there is a continuous animal turnover thus resulting in a condition known as disease build-up (Saldivar, n.d.). Maintaining an infection free animal shelter can be nearly impossible considering the dirt and feces that can be present throughout. According to Saldivar, disease causing bacteria, viruses, fungi, and parasite eggs accumulate in these types of environments and can become immune to improperly applied disinfectants, thus transmitting disease to the animals being housed.

Zoonosis: A Disease passed from Animals to Humans

Zoonosis or zoonotic disease refers to diseases that can be passed from either wild or domesticated animals to humans. Although many diseases are species-specific or only passing within one animal species, many other diseases can be spread between different animal species. These infectious diseases can be caused by a variety of bacterial species, viral species, or other organisms capable of producing disease. These agents can dwell in animals as well as humans and a variety of environmental conditions.

As humans and animals experience more over crowding, there is a growing fear that more zoonotic diseases will jump the species barrier. This problem is most visible in current outbreaks of SARS and Avain Flu, which have appeared out of Asia where animals and humans live in close proximity to each other. Some experts fear that diseases like the Avain Flu can mutate and spread easily among humans (Orent, 2005).

Fear of animal originated disease does not only affect people in third world countries. An article published by Dr. Thu (2002) in the Journal of Agriculture Safety and Health found that there is emerging concern related to health effects of people living near confined animal feeding operations, especially large swine operations. In the U.S., large swine, cattle, and poultry operations are found throughout the country, not only in rural settings, but also in areas heavily populated by humans.

Prevention and Control of Animal Disease

Preventing infectious disease and illness in animal holding facilities can incorporate a number of activities. As mentioned above, vaccination is great way to protect animals from potential infection. The drawbacks to vaccinations are they may not prevent the animal from contracting the disease it was vaccinated against. Another issue with vaccines is that they are not available for many illnesses which animals may be exposed to.

As with human infections in health care settings, the incorporation of multiply prevention measures needs to be implanted in animal health. This would include the addition of an effective disinfection program to go along with vaccination and animal handling procedures. A problem which impacts many animal handling facilities is the fact that many of the building are quite large, making disinfection a huge task (Saldivar, n.d.). Another issue is the limited manpower available to perform needed disinfection.

Because of the factors mentioned above, ozone technology may prove to be a valuable disinfection tool. Ozone is not only an effective broad-spectrum antimicrobial but because it is can be used in gaseous form it can give a complete coverage of all surfaces. Certain ozone technology can also be applied with very little manpower once it has been installed.

Livestock producers and animal care professionals have several different applications where ozone technology may be very beneficial. Wastewater and organic matter handling is a major concern for swine and cattle facilities. Studies have shown ozone to be an effective tool in the treatment of these waste products (Watkins et al., 1997).

Another area of concern to animal handlers is need for an environmental air treatment for confined animals. Ozone as an environmental air treatment is becoming popular in both poultry and pork facilities. Producers are seeing improved average daily gain, feed conversion and reduced death loss from dispersing ozone into the air. The reduction of noxious gases such as ammonia and hydrogen sulfides has also been found with ozone applications in livestock operations (Hill & Bernuth, 2002).

Invasive Medical Devises and Clean Rooms

Medical Devises

Invasive medical devises have become a larger issue with the development of new medical treatments. Invasive devises used in treatment of patients such as intravenous catheters are allowing for additional sources for infection. It is estimated that catheters use in hospitals alone account for 50,000 to 100,000 bloodstream infections each year in the United States (Chotani et al., 2004). Ventilators are another category of medical devices which are a source of nosocomial infections. Ventilator-associated pneumonia remains a major issue in most health care facilities (Myriantbefs et al., 2004).

Improving the design of invasive devices may be one of the most critical factors in controlling health care related infections. This is especially important given the increase in incidence of vascular access–associated bloodstream infections. Weinstein stated "Given the choice of changing human behavior (e.g., improving aseptic technique) or designing a better device, the device will always be more successful". The development of noninvasive monitoring devices and minimally invasive surgical techniques that avoid the high risk associated with bypassing normal host defense barriers (e.g., the skin and mucous membranes).

Infection concerns from invasive devices in chronic care facilities may be of greatest concern due to the extended time patients are exposed to the devices. However, their impact on infections has not yet been thoroughly evaluated (Nicolle, 2001). Preventive strategies need to address the changing complexity of care in these facilities, especially the increased use of invasive devices. The anticipated increase in the elderly population in the next several decades makes prevention of infection in long-term care facilities a priority (Nicolle, 2001).

There have been increased efforts to make invasive devices safer. However there is much more that needs to be done, including the development of new disinfectant technologies. Recently an application for UV light technology was patented for use in disinfection of medical devises (Ruane et al., 2004). Ozone technologies have many of the same advantages as UV light technology. Ozone also has the advantage of being a gas which can result in better coverage of the devices.

Infection Control in Clean Rooms

Clean rooms are used in many industries including food, beverage, pharmaceutical, research, analytical testing, and semiconductor production. Clean rooms are rooms which have had precautions put in place to make the free from possible biological contamination. The cost for maintaining a high level clean room can be expensive and obtaining of necessary funding to build these rooms can often be difficult (Talley, 2003).

Current methods for controlling the environment in clean rooms include HEPA filters, which can be expensive to maintain, and chemical cleaners, which are relatively inexpensive but have other issues. Clean rooms are designed for the purpose of reducing the particulate dust content via air recycling. Considering that you may have a dozen chemicals in the clean room at any time, the fumes and vapors are constantly entering and not being filtered out (Tenenbaum, 2003). The exposure to possibly toxic chemicals to persons working in the clean room is a real concern (Tenenbaum, 2003).

Pharmacy compounding rooms are used by most hospitals to prepare medications for patients. These rooms are often used to prepare sterile intravenous admixtures in hospitals. These rooms are often insufficient in there designs to maintain a sterile environment (Talley, 2003).

Ozone technology has the potential for application in clean rooms as a disinfectant and as a safer alternative than some current disinfectant chemicals. The low cost of ozone technology may also be appealing for industries who can not afford some of the more expensive clean room technologies.

Water Quality

Water Safety, Contamination, Recycling Issues

The safety of drinking water is of vital importance to public health (WHO, 1996). Protecting the source of the water supply is usually accepted as the principal approach towards obtaining microbiologically safe drinking water. However, many sources are highly polluted and need extensive treatment before distribution to the consumer (Havelaar et al, 2000). Chemical disinfection is an important factor in water treatment systems. Oxidizing chemicals such as chlorine and ozone kill a variety of pathogenic microorganisms during treatment, and chlorine is applied in many countries as an additional safeguard in the distribution system. An important drawback to the use of these chemicals is the generation of disinfection by-products, which have suspected adverse effects on human health (Havelaar, 2000).

Cryptosporidium parvum, is a leading cause of persistent diarrhea in developing countries, and is a major threat to the U.S. water supply. *Cryptosporidium parvum* has caused major outbreaks of waterborne disease in Europe and in North America (Mac Kenzie et al., 1994). Cryptosporidium is found in untreated surface water, as well as in swimming and wade pools, day-care centers, and hospitals. The organism can cause illnesses lasting longer than 1 to 2 weeks in previously healthy persons or indefinitely in immunocompromised patients. Other pathogenic microorganisms, such as viruses and *Campylobacter jejuni*, may also be present in similar concentrations in water from storage reservoirs. However, these organisms are inactivated by post disinfection processes such as UV irradiation in our scenario and hence cause smaller public health problems (Havelaar et al., 2000). Adequate control of *C. parvum* is therefore of critical importance in most surface-water supplies. Infection with *C. parvum* may result in self-limiting gastroenteritis in immunocompetent persons. In those who are immunocompromised, the infection is not easily cleared and usually results in severe life-threatening gastroenteritis (Havelaar et al., 2000).

Water safety is not only an issue in drinking water and wastewater management but is other uses such as swimming pools and whirl pool footbaths. A study by Leoni, Legnani, and Pirani (1999) found that 88 % of pool waters tested had mycobacteria present. In 2000 an outbreak of rapidly growing *Myobacterium fortuitum* caused localized cutaneous infections in a California nail salon. It is believed that water entered the footbaths through the municipal tap water and thrived in large amount or organic debris accumulated behind the foot spa recirculation screen (Vugia et al., 2005). A study by Vurgia and associates found that 97% of the footbaths tested had mycobacteria present. The nail care business is estimated to be a $6 billion dollar industry (Vurgia et al., 2005).

The use of ozone in water treatment has been a big success. Researchers have found ozone to be an excellent disinfect, especially for the treatment of water and waste water (Chiang et al., 2003). The main reason is its ability to destroy microorganisms more effectively than other chemical treatments. *Cryptosporidium parvum* oocysts are resistant to chlorination but are inactivated by ozonation, which is increasingly used as an alternative disinfectant (Havelaar et al., 2000). Other studies have shown ozone to be effective in reducing populations of coliforms, *E.* coli, and *Pseudomonas aeruginosa* by at least 99% in waste waters (Chiang, Tsai, Lin, Huo, & Lo, 2003). Ozone has shown to be an excellent disinfectant for destroying spore-forming bacteria and viruses (Mork, 1993).

Unpleasant odor in water is also a concern for water treatment facilities, requiring the removal of sulfides from the water. Ozone is a strong oxidizing agent as well as an effect disinfectant. The oxidation of sulfide with ozone has shown to be a fast and effective means of treatment. According to Mork (1993), contaminated water can be taken to a potable stage in mere seconds.

Hospitality and Travel Industries

The airline industry has been a concern for the spread of infectious disease, especially since recent SARS outbreaks. To save fuel airlines have cut back the air flow in passenger compartments. Many of those persons who regularly fly in commercial airlines are complaining of stale air on long flights. According to a 2001 paper (Haavind, 2001) the public should demand that treatment systems be installed to kill all bacteria and viruses being circulated through passenger cabins. Haavind also states “As people from all over the world are thrown together on long flights where there is an exchange of unfamiliar microbes for which most passengers do not have adequate antibodies (p. 12).” This leads to the spread of infectious disease such as influenza and other more serious illnesses, especially after trips abroad. Filtration might remove bacteria, but not tiny viruses (Haavind, 2001). Between flights, some quick infectant spray-and-wipe on areas such as seat-arms, door handles, and sinks should also be required. Haavind also believes that sufficient, virus and bacteria-free air should be required by Congress and the FAA as a condition for airlines to fly highly profitable routes all over the world.

The cruise line industry attracts millions of visitors every year, coming from all over the world. Elderly travelers and other passengers with health problems are at increased risk of complications of infection (Miller, 2000). Every year the number of outbreaks due to infectious diseases, such as norovirus or influenza increase. In 2002 alone the CDC (2002) reported 21 outbreaks of acute gastroenteritis on cruse ships with foreign itineraries sailing into U.S. ports. An investigation by Miller and associates (2000) found that cruise ships are very much like other high risk health care settings (such as nursing homes) where high risk individuals are more often exposed to infectious diseases. Activities such as gambling, dining, movies, and tours help promote the spread of infectious diseases.

The air-quality in most hotel guestrooms is likely more polluted and dirtier than most homes (Thompson, 1999). To make building more energy efficient many hotels allow for very little air circulation causing particulates, odors, molds, bacteria, and cleaning fumes to be trapped in the guest rooms. A recent article in The Wall Street Journal reported that an alarming number of hotels have sub-standard air quality in their guestrooms. The typical symptoms travelers experience are sore throats, headaches, and burning eyes. These symptoms are likely reactions to poor indoor air quality (Thompson, 1999).

Prevention and Control of Infectious Disease by Travelers

It has been recommended that all possible modes of infectious disease transmission and air pollution be addressed in the airline travel, cruise ship, and hotel industries (Thompson, 1999). This would include control measures directed toward food safety, healthy environmental conditions, and person to person contact (Isakbaeva et al., 2005). All of the above mentioned measures should include extensive disinfection to meet these goals (Isakbaeva et al, 2005). Current disinfection procedures, such as chlorine used on surfaces, are effective but can also be corrosive to fabrics, carpets, wood, and metal surfaces. Chemical treatments also need to be constantly repeated to assure that contamination doesn't reoccur.

The use of ozone technology may be best suited for application in the travel and hospitality industries. Ozone generators clean the air and may reduce the risk of microbiological infections. Applications of ozone are generally quick and easy as units are portable and only require a minimal amount of time to treat the average room.

Unpleasant odors and stale air are also common complaint of traveler's. Ozone generators may help rooms and lobbies smell fresher and cleaner. As mentioned early, ozone has been shown to be effective at removing cigarette smoke odors (EPA). Ozone may also be an effective way to reduce room cancellations and complaints by guests due to unpleasant odors (Haavind, 2001).

Bioterrorism & Biosecurity Preparedness

Bioterrorism has become a focus of this country since the events of September 11, 2001 and the Anthrax mailings that same year. Infectious agents have been and will, in the anticipated future, remain potential weapons of mass casualties (Weber, 2004). In the past, out-breaks of infectious diseases have killed far more people than wars themselves. Biological agents have been used in warfare since ancient times. Their use to terrorize civilians by individuals, groups, and states is more recent and a consequence of the ease in cultivating microorganisms (Weber, 2004). In addition, a number of other biological agents and toxins have potential use as biological weapons. According to Hagstrom (2001), some lawmakers are worried that the threat to the nation's fields, livestock feedlots, research laboratories, and grocery stores could be overlooked by the more immediate concern about bio-terrorist threats to human life.

Biosecurity is defined as the exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health. It covers terrestrial, freshwater and marine environments (Meyerson & Reaser, 2002). Biosecurity is a challenging and vital topic of intense concern in nearly every field of global biological, socioeconomic, and political systems.

Prevention of bioterrorism or biosecurity events should be aimed at securing the nation`s points of entry, as well as the length of our country's natural borders, against the passage of pathogens not yet in the United States (Sherwood, 2005). Security of our airports should involve more then just a physical threat. The recent outbreak of SARS taught us that biological threats are real and can be dispersed throughout the globe via our airlines (Lancelot, 2005).

The need for better quarantining procedures is not just limited to humans but also for pets, livestock, plants, and produce entering the country. According to Wheelis, Casagrande, & Madden (2002), there is currently a large loss by agriculture producers from diseases that affect livestock and crops. Approximately $17 billion are lost each year because of diseased livestock and approximately $30 billion dollars in crop damage from disease (Wheelis et al., 2002).

Ozone may play a vital role in the prevention and control efforts for bioterrorism and biosecurity threats. According to Dr. Sherwood, University of Georgia, what are needed most are strategic applications such as chemicals to combat disease that will be used at low application rates, pose minimal environmental risk, and have a low potential for the development of pathogen resistance. Ozone technology has the potential to meet all of these criteria. In June 2003, the Chinese government implemented its use to help prevent the spread of SARS and other highly infectious diseases.

Mailings of envelopes contained anthrax spores created serious disruption of business operations in various parts of the U.S., and even resulted in the loss of human life from exposure to anthrax. According to Rice (2002) "ozone clearly is a sufficiently powerful oxidant to destroy *Bacillus anthracis* in relatively short exposure times. Research on ozone is needed to fill data gaps and to convince government authorities in charge of antiterrorism activities that ozone should be included as a prime candidate for combating anthrax contaminations".

Overview of Ozone Technology and Misconceptions

Methods of Ozone Production

Ozone is produced from oxygen as a result of electrical discharge or ultraviolet (UV) radiation. Oxygen atoms are formed by splitting of diatomic oxygen molecules into two atoms, which then recombine with other oxygen molecules to produce ozone molecules. Ozone produced for commercial application is generated by corona discharge, UV radiation, and electrolysis.

The corona discharge method uses oxygen (or dried air) passed between two closely spaced electrodes under a nominal applied voltage of ~ 10 kV. Corona discharge ozone generators commercially currently available are capable of producing ozone in gas phase at levels of 1 to 5% by weight in air and up to 14% by weight in high purity oxygen (Khurana et al., 2003).

In the UV radiation production of ozone the process is similar to the photochemical production which occurs in the stratosphere. Oxygen atoms formed by the photo-dissociation of oxygen by short wavelength UV radiation react with oxygen molecules to form ozone. An advantage of using UV radiation to produce ozone is that ambient air can be used efficiently as a feed gas (Khurana et al., 2003). The low concentration achieved by UV radiation may not work well for water applications but are ideal for air treatments where high concentrations are not required.

High current density electrolysis of aqueous phosphate solutions at room temperature produces ozone gas. Electrolysis of sulfuric acid can produce very high ozone concentrations in oxygen when well cooled cell is used. Low ozone concentration produced by this method make it less effective at destroying microorganisms. Ozone produced by UV, in comparison, is produced at the ideal concentration required to destroy airborne bio-aerosols and volatile organic compounds (Khurana et al., 2003).

Advantages of Ozone Technology

One of the biggest advantages of ozone may be its relatively low cost in comparison to other technologies.

- Ozone will neutralize virtually all organic odors, specifically those that contain carbon as their base element.
- Ozone is also less corrosive to equipment than most chemicals currently being used, such as chlorine.
- Ozone generators clean the air and may reduce the risk of microbiological infections.
- Applications of ozone are generally quick and easy as units are portable and only require a minimal amount of time to treat the average room.
- Ozone has been found to be an excellent disinfect, especially for the treatment of water and waste water.
- Ozone is not only an effective broad-spectrum antimicrobial but because it is can be used in gaseous form it can give a complete coverage of all surfaces.
- Ozone technology can be applied with very little if any manpower.
- An important advantage of ozone used in food processing is the product can still be called organic.
- Ozone kills bacteria within a few seconds by a process known as cell lysing. Because of this, microorganisms cannot develop ozone resistant strains; thus eliminating the need to change biocides periodically

Disadvantages of Ozone Technology

Because ozone cannot differentiate between good organic molecules and bad, it can, in excessive amounts, oxidize us. As a result, a progressive approach to all oxidizers, including ozone and chlorine, is to use them with all appropriate safety precautions and at levels recommended by manufactures. When high level ozone exposure occurs to humans possible side effects include coughing, irritation of the throat, and/or uncomfortable sensations in the chest. These symptoms can last for a few hours after ozone exposure.

Health effects for high level ozone exposure are a genuine concern and should be looked at before using the technology. Studies have shown that when ozone levels are high, more asthmatics have asthma attacks that require a doctor's attention or the use of additional medication. Asthmatics are more severely affected by the reduced lung function and irritation that ozone causes in the respiratory system (Delfino et al., 1996). It should be noted that most of these studies have been conducted based on outdoor ozone levels.

The appropriateness of high level ozone for use in unoccupied spaces has been raised by some researchers. Ozone is sometimes used to treat homes, furniture, and clothing after fires to remove smoke odors. Consumer’s Research Magazine noted that

"Ozone is a strong oxidizer that will accelerate the degradation of rubber, upholstery, paints, and other materials. Thus, even when used in unoccupied areas, ozone generators can cause damage to building materials and electronic devices ("*Hazards of ozone*", 1998)." Typically, restoration companies which use high level ozone generators recommend covering of household product that might be affected by the ozone.

A concern about the use of ozone generators is that they can produce unsafe ozone levels in the rooms where they are used. U.S. EPA (1993) research has shown that there are some devices on the market that are capable of producing ozone concentrations well above those of accepted health guidelines. Not all ozone units include controllers to prevent ozone levels from exceeding safe limits. Ozone gas initially produces a sharp odor; however, it dulls the sense of smell after a brief period of continuous use. Hence, perceived odor is not a reliable indicator of ozone's presence ("*Hazards of ozone*", 1998).

Misconceptions about Ozone Technology

Probably one of the biggest misconceptions regarding ozone technology is that all air cleaners sold for residential use are inherently dangerous. Even the U.S. EPA found that ozone monitors tested under manufacturers recommended conditions, produced ozone generation rates normally within the ranges stated by the manufacturers. When used properly and safely, there seems to be little concern of a serious health risk.

Millions of ozone air purifiers have been sold in the United States over the years, but there are no specific cases where an ozone air cleaner has been linked to any kind of harm or injury. In June, 2001 the U.S. Food and Drug Administration (the FDA) formally approved the use of ozone in gaseous (air) and aqueous (water) phases as an antimicrobial agent on food, including meat and poultry.

Well-intentioned but misinformed people mistakenly equate ozone with low-altitude pollution or smog. This is because whenever smog levels are high, so are the measured ozone levels. Ozone is easy to measure; hydrocarbons are not. They're just too complex. Since ozone is always present in levels consistent with the hydrocarbon (pollution) level, the assumption is perpetuated that it's the ozone that is the culprit. However, nothing could be further from the truth. Ozone forms naturally when sunlight reacts with man-made hydrocarbons in the air (automobile exhaust or smokestack emissions, for example). The more hydrocarbons there are, the more ozone is produced–and and it's the ozone that is actually breaking down those harmful pollutants and rendering them harmless. Without ozone, we couldn't even live in our cities!

What some refer to as ozone in ground-level air quality are really hydrocarbons: CO_2 CO and SO_2 that react with UV rays from the sun to form nitric oxides (NOX), halogenated by-products, lead and sulfur compounds (Mork, 1993). These composites cause offensive odors and do indeed aggravate respiratory problems and burn eyes. But this is not the ozone being produced by many current air purifiers. According to H. Banks Edwards, author of the article, "Indoor Air Quality: A Different Approach," there is both good and bad ozone.

"Most of the ozone standards were developed before 1950 using ozone generators that were crude when compared to today's equipment. The ozone used for their experiments was generated from air. Since the primary ingredients of air are oxygen and nitrogen, when ozone is generated from air, the products are ozone and nitrous oxides. Both nitrogen oxide and nitrous oxide are toxic to the respiratory system. Pure ozone is not. Therefore if the nitrogen products are removed from the ozone, the toxicity would be eliminated. Ozone made from pure oxygen will produce only ozone and oxygen. Ozone generated from air is called impure ozone, but ozone made from oxygen is called pure ozone."

Another misconception about ozone is that it produces harmful toxins when added to water. Bromate is considered the most important by-product of ozonation (Weinberg & Glaze, 1996). Ozone reacts with bromide ions to produce bromate. Bromate has been shown to induce tumors in the rat kidney, thyroid, and mesothelium and is a renal carcinogen in the mouse (DeAngelo et al., 1998). Other by-products from ozonation may include aldehydes, bromoform, and brominated acetic acids, none of which are classified as genotoxic carcinogens. However, studies have shown that at usual ozone doses only formaldehyde is produced in measurable quantities, at levels far below the WHO (1996) guideline of 900 mug/L (Marinas, Rennecker, Teefy, & Rice, 1999).

The loss of the sense of smell (anosmia) has been implied as a side effect of low level ozone exposure. However, there is no evidence to support this claim. This assertion may have originated from the fact that ozone is effective at eliminating odors, especially organic based odors such as cooking.

Low Level Ozone for Aerial Disinfection

One of the most heavily debated issues is the effectiveness of ozone as an aerial disinfectant. Many believe that ozone is effective only at very high levels, which are unsafe for human exposure. Others claim that it is effective at destroying bacteria at levels safe for human exposure. The truth ozone's is an effective antimicrobial agent at low levels but its effectiveness is dependant on a number of factors. Just like may other oxidative chemicals, disinfection rates for ozone are dependant on the type of organism, treatment time, temperature, relative humidity, pH, the presence of ozone-oxidizable materials, the tendency of microorganism to form clumps, and type of ozone contractor. Humidity is one of the most crucial factors with studies showing that as an airborne antimicrobial, effectiveness is optimized at levels higher than 45% RH (relative humidity) (Elford & Ende, 1942). Testing at levels below 45% RH gave inconclusive results.

There is a limited amount of data available on the research done with ozone at low concentrations. In Table 1, Kowalski et al. (1998) compiled data on ozone used for reducing bacteria and viruses populations reported by previous investigators.

Table 1. Ozonation of bacteria and viruses in air (Kowalski et al. (1998)).

Test Organism	Ozone (ppm)	Time (sec)	% Reduction	Investigator
S. salivarius	0.6	600	98	Elford et al. (1942)
S. epidermis	0.6	240	99.4	Heindel et al. (1993)
pX174 (virus)	0.4	480	99.9	De Mik (1977)

Studies conducted by Midwest Research Institute (Huebner, 2003), using 0.05 ppm also showed reductions in five different pathogens. Reductions is *Escherichia coli, Staphyloccus aureus, Salmonella choleraesuis*, and *Penicillium chrysogenum* populations were between 30% and 70%, following 6 to 24 hour exposure. Reductions of *Candida albicans* were even greater at 90%.

Government Regulations and Health Effects

In the following Table 2, government guidelines listed for use of ozone technology are listed along with information on health effects and risk factors.

Table 2. Ozone Heath Effects and Standards

Health Effects	**Risk Factors**	**Health Standards***
Potential risk of experiencing: Decreases in lung function Aggravation of asthma Throat irritation and cough Chest pain and shortness of breath Inflammation of lung tissue Higher susceptibility to respiratory infection	Factors expected to increase risk and severity of health effects are: Increase in ozone air concentration Greater duration of exposure for some health effects Activities that raise the breathing rate (e.g., exercise) Certain pre-existing lung diseases (e.g., asthma)	The Food and Drug Administration (FDA) requires ozone output of indoor medical devices to be no more than 0.05 ppm. The Occupational Safety and Health Administration (OSHA) requires that workers not be exposed to an average concentration of more than 0.10 ppm for 8 hours. The National Institute of Occupational Safety and Health (NIOSH) recommends an upper limit of 0.10 ppm, not to be exceeded at any time. EPA's National Ambient Air Quality Standard for ozone is a maximum 8 hour average outdoor concentration of 0.08 ppm
(* ppm = parts per million)		

U.S. EPA (1999)

Summary and Recommendations

Summary of ozone technology

Ozone has been found to be an excellent disinfect and deodorizer, especially for treatment of water (Chiang et al., 2003). Used for many years by professional cleaning companies, ozone technology has been proven effective as a disinfectant in sick houses, hotels, restaurants, and businesses. As a deodorizer, ozone has shown to be a valuable means for removing unwanted smells, especially organic based odors such as those from cooking and pets.

Research has found that ozone levels of less then 9 ppm are necessary for sick buildings or professional disinfection (Khurana, 2003). Even lower levels of ozone (less than 0.1 ppm) have been shown to be effective at reducing populations of bacteria, fungus, and viruses. The use of ozone to help prevent infections in both humans and animals has just recently become a viable application with the advent of safer ozone technology. The food industry has also recently begun to apply ozone technology in a variety of ways to make our food supply safer and more wholesome. The function of ozone technology in the area of biosecurity and bioterrorism is just beginning to be explored but has great potential.

Recommended uses for ozone

Ozone has great potential for use is many different applications. Due to the high cost of health care acquired infections, both in lives and dollars, there is an impending need for better and more accessible disinfection technology available to homes, schools, health care facilities and businesses. According to Rice (2002) it is important that those in the ozone industry be aware of the known facts and data gaps concerning ozone. This will minimize the number of well-intentioned over claims for ozone that give ozone a bad name. The application of ozone technology should be tested in areas where current technologies and/or procedures for disinfection and odor control may be lacking.

How to choose an ozone technology for your application

In choosing the ozone technology which best fits your specific application it is strongly advisable to check with a reputable manufacturer to help you. As you have seen in the previous sections, ozone can be used in a wide range of industries and in many different forms. Making sure that it is used in a safe and responsible manner should be of utmost priority.

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