
# Ozone for Improving Indoor Air Quality – Myths and Realities

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# OZONE FOR IMPROVING INDOOR AIR QUALITY – MYTHS & REALITIES

There is a growing concern about the indoor air pollution as more and more people report symptoms or specific diseases in air-conditioned buildings. Depending on which building you work in and in which area of the city you live in "indoor air can be up to 10 times more polluted than outdoor air". Strange, as this may sound, the fact remains that the air we breathe, working or living, 85% of the time in conditioned spaces may be more injurious to health than outdoor air.

Over the last 15 years, our knowledge of environmental risk to public health due to poor air quality has increased dramatically. Science advisory boards have consistently ranked indoor air pollution among the top five environmental risks to public health. Poor indoor air quality leads to an increased incidence of health related symptoms, which in turn can lead to an increase in absenteeism and loss of productivity.

## What is Indoor Air Quality?

Indoor Air Quality (IAQ) refers to the nature of conditioned air that circulates throughout the space/area where we work and live, that is, the air we breathe during most of our lives. IAQ refers not only to comfort, which is affected by temperature, humidity and odors, but, also to harmful biological contaminants and chemicals present in the conditioned space.

Most people control the environment in their homes to a degree, which is comfortable and healthy for them. They will open windows if the room feels stuffy and unaired; they will use exhaust fans in the kitchen and toilets to clear smoke and odors; they will not use freshly painted rooms until the smell has gone away. Although, by such practices they can avoid immediate adverse effects, they may not have enough awareness of the long-term effects, of the paint removing chemicals used during refurbishing, which may increase the risk of heart or liver disease, or the long term effect of exposure to insecticides being commonly used.

What is easy to accomplish by an automatic behavior at home is much more difficult to accomplish when applied to buildings inhabited by people of widely varying sensitivities and sensibilities. In many modern large commercial structures, for example, occupants have virtually no control over the environment, they cannot open windows; they cannot turn on exhaust fans and cannot leave the room if a colleague has severe cold and cough. They have no control over the atmosphere in a cinema hall, which smells stuffy and unaired, when they walk in; restaurants or banquet halls, which smell stale and damp or boardrooms with heavy smoke filled air.

**WHAT CAUSES IAQ PROBLEMS IN CONDITIONED SPACES?**

Not enough outdoor air, poor air quality or poor air circulation.

In the past few decades, energy conservation measures have resulted in tighter buildings with recirculated air for building ventilation and minimum amounts of fresh air being brought into the buildings. This minimized the amount of air to be heated or cooled and hence conserved on energy but at the same time since free passage of air is limited, with little or inadequate fresh air ventilation, it produces an indoor air environment with relatively high levels of contaminants, bacteria, fungi and dust. The indoor air will certainly have all of the pollutants of the outdoor or surrounding air and those, that are generated within the building by people and their activities like smoking, hair sprays, cleaning products, paints and pesticides spray residues, carpeting, copy machines and air-conditioning coolants. As a result, indoor air may contain a concentration of some components which are greater than the outdoor ambient air. The composite effect of multiple pollutants result in a situation described as the 'Sick Building Syndrome' (SBS), a term which was used to describe the presence of acute non specific symptoms in the majority of people, caused by working in buildings with an adverse indoor environment. SBS can seriously impact human respiratory systems leading to various short term and long term illness and is suspected when a substantial portion of the people spending extended time in a building report or experience acute on site discomfort.

**TYPES OF AIRBORNE CONTAMINANTS**

Airborne contaminants are unwanted materials in the air, which are harmful for human health. These enter the building through the HVAC systems or are carried by building occupants or are generated within the building surfaces. The pollutants of our concern can be divided into three groups:

1. Particulates
2. Gaseous contaminants
3. Microorganisms

**Particles -** Particles are very small solid or liquid substances that are light enough to remain suspended in air (e.g., mists, dust, or pollen). Of primary concern from a health standpoint are: 1) small, invisible respirable-size particles, with a higher probability of penetrating deep into the lungs, where they may stay a long time and may cause acute or chronic effects, and 2) larger particles, such as some molds, pollen, animal dander, and house dust allergens, which do not penetrate as deeply, but may cause an allergic response.

**Gaseous pollutants -** The gaseous contaminants are actually collections of molecules – unlike particulates – and are best distinguished from particulates by size. Very small particulate matter may be about 0.12 microns in diameter, while gas-phase contaminants are typically only a fraction of nanometer i.e., about 30,000 – 40,000 times smaller. Gaseous contaminants have harmful or annoying effects on the ventilated space or its occupants. These effects are noticeable at different concentration levels. In most cases, contaminates become annoying by their odors before they reach levels toxic, even deadly.

Gaseous pollutants include gases, such as carbon monoxide, sulfur dioxide, nitrogen oxide, nitrogen dioxide, formaldehyde and many other volatile organic compounds (VOC) released from the use of products such as paints, adhesives, veneer, polish, dyes, solvents, caulks, cleaners, deodorizers, personal hygiene products, waxes, hobby and craft materials, and pesticides. These contaminants generate within the building and travel from sources outside the building via infiltration or the HVAC system air intakes located too close to roads, loading docks, and trash dumpsters or exhaust vents.

**Microorganisms -** The most common microorganisms found in a building include fungi, bacteria and viruses. Except for viruses and certain bacteria, most contaminants are larger than 1 micron in diameter. Microorganisms have long been ignored by HVAC system designers and managers, but increasing concerns about indoor air quality (IAQ) have focused attention on the need to limit the concentration of microorganisms.

**STRATEGIES FOR INDOOR ENVIRONMENTAL CONTROL**

Methods for controlling contaminants fall into three categories:

1) Source Control - Suppressing the generation rate;

2) Removal control - Arrestance by extraction devices;

3) Dilution control - High rates of air changes per hour.

Control of pollutants at the source is the most effective strategy for maintaining clean indoor air. Control or mitigation of all sources, however, is not always possible or practical. Ventilation, either natural or mechanical, is the second most effective approach to providing acceptable indoor air.

**Source Control**

Usually the most effective way to improve indoor air quality is to eliminate individual sources of pollution or to reduce their emissions. Some sources, like those that contain asbestos, can be sealed or enclosed; others, like gas stoves, can be adjusted to decrease the amount of emissions. Source control of volatile organic compounds (VOCs) like formaldehyde can be accomplished by selecting and using low-emitting products (Furniture, building materials, paint, cleaning chemicals, textiles and office equipment like printers) in the indoor environment. Select products that have been tested and verified by reputable third-party certification programs like Green Seal and Green Guard. This will ensure that products have been tested and found to conform to the most stringent standards for low impact on the indoor environment. Source of allergens is generally from pets, dust, mold and insects.

Some of the simple source control methods would be:

- Banning smoking or providing a separated ventilated space for smokers.

- Using and storing paints, solvents, pesticides, adhesives in closed containers in well ventilated areas.
- Using these pollutant sources in periods of low or no occupancy.
- Allowing time for new building materials to gas off before occupancy.
- Fixing any water leaks.
- Replacing water stained ceiling tiles or carpets and drying.
- Control of humidity to safe level so that mold, fungus and algae formation are prevented.
- Regular maintenance of HVAC systems including duct cleaning.
- Providing efficient filtration in the HVAC system for keeping outdoor pollutants out.
- Exhaust air from rest rooms, copy rooms and printing facilities directly to the outside.

Unfortunately, not all pollutant sources can be identified and practically eliminated or reduced via source control alone.

**Removal Control (Air Cleaners & filtration)**

Air cleaners are usually classified by the method employed for removing particles of various sizes from the air. There are five general types of air cleaners on the market: mechanical filters, electronic air cleaners, chemical filters, UV systems and ion generators. Hybrid units, using two or more of these removal methods, are also available. Air cleaners may be in-duct units (installed in the central heating and/or air-conditioning system) or standalone portable units.

1. Mechanical filters: These operate by passing the airstream through the filter media, where fibers of the filter trap the airborne contaminants. The success of filtration systems depends on their ability to capture the right contaminants in the right quantity; factors that depend to a great extent on the type of filtration system installed. These are available in a number of different configurations, including flat panels, pleated panels, blankets and bags. Most panel type filters have a rated

efficiency of 40 percent or less and can trap particles as small as 1 micron. HEPA high-efficiency particulate air filters typically have efficiencies of 99.9 percent and can remove particles as small as 0.1 micron.

2. Electronic cleaners: Electronic cleaners also called “electrostatic precipitators” use electrostatic charges to attract particles to collecting plates, where they are held by an adhesive coating. They offer relatively high operating efficiency at a low pressure drop across the filter. Most can remove particles as small as 0.01 micron. They are particularly effective at removing fine dust and smoke particles.

3. Chemical absorbers: use carbon, activated charcoal, permanganate oxidizers or proprietary chemical compounds installed in a rack to remove gases and volatile organic contaminants. While efficiencies vary with the design of the filter system, most can remove vapors and gases as small as 0.0003 microns. These are one of the most effective means of reducing exposure of occupants to gases and VOCs; however, because of cost and maintenance requirements, these systems are not generally used in normal occupancy buildings.

4. Ultraviolet (UV) systems are designed to kill many microorganisms found in the airstream. Installed downstream from an HVAC system’s cooling coil, the lights help reduce biological growth on the coil itself and within the ductwork. Since this type of air-filtration system does not remove any particulate matter from the airstream, it is usually installed along with another type of air filter system.

5. Ion generators: Ion generator also called “an ionizer” is a device that disperses negatively and/or positively charged ions into the air. These ions attach to particles in the air giving them a negative (or positive) charge so that the particles may attach to nearby surfaces such as walls or furniture, or attach to one another and settle out of the air. In recent experiments, ionizers were found to be less effective in removing particles of dust, tobacco smoke, pollen or fungal spores than either high efficiency particle filters or electrostatic precipitators (U.S. EPA, 1995).

Some of the air cleaners containing sorbents may also remove some of the gaseous pollutants in indoor air. However, no air-cleaning systems are expected to totally

eliminate all hazards from gaseous pollutants and these systems may have a limited lifetime before replacement is necessary.

**Dilution Control (Ventilation)**

Ventilation brings outside air into a specific zone or exhaust air outside for dilution. Over the years, there's been an increased focus on energy efficiency, leading to buildings that are more airtight. However, when a building is tightly sealed, the amount of air exchange with the outdoors is reduced. While this may improve energy efficiency, it reduces ventilation and subsequently increases the accumulation of contaminants in the indoor air. Adequate, clean and well-distributed outside air needs to be circulated within the indoor environment. Localized exhaust is also important, especially in cleaning supply rooms, or environments where chemical emissions or other contaminants are likely to be elevated.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has established standards ASHRAE 62 "Ventilation for Acceptable Indoor Air Quality" that govern the proper application and amount of ventilation to provide acceptable IAQ. It is the de facto standard for ventilation recommendations in the United States and the 2001 version of ASHRAE Standard 62, offers two options for maintaining adequate ventilation:

1. Ventilation rate procedure and;
2. Indoor air quality (IAQ) procedure.

The **ventilation rate** procedure uses the traditional prescriptive method, i.e. supplying a minimum quantity of outside air in cubic feet per minute (CFM*)* per person. ASHRAE Standard 62-1989 recommends fresh air intake of 20 cfm per person. A designer typically using this approach would determine the maximum occupancy of the space and multiply this with the recommended CFM-per-person. The resulting "design ventilation rate" would be provided continuously to the space during occupied hours. Obviously a constant design ventilation rate based on a full occupancy will lead to waste of energy during lean periods when the room is empty, or when only a few people are in the room.

Excessive ventilation will not improve the comfort level of occupants in a zone, but it will increase energy usage since any extra outside air must be conditioned and delivered to the zone. The **IAQ** procedure allows designers to vary the outdoor air (OA) ventilation rate. The usage pattern, and consequently the ventilation requirements of room can vary largely depending on several parameters, e.g. type of building, activities and purpose of the room, climatic (outdoors) conditions and time of the day. Just think of a shopping mall or an auditorium, where the occupancy pattern changes from low to high several times every day.

Two most commonly addressed technologies using IAQ procedure are:

1. Demand Control Ventilation using $CO_2$ sensors
2. Ozone Enrichment

**DEMAND CONTROL VENTILATION USING $CO_2$ SENSORS**

$CO_2$ or carbon dioxide has been recognized by ASHRAE as the surrogate ventilation index or the only measurable variable. A carbon dioxide level in air-conditioned spaces is a good indicator of occupancy and ventilation rate within a space. $CO_2$ by itself is not considered an indoor air contaminant and people are the major source of $CO_2$. If the number of people in a room is doubled, the $CO_2$ level will also double. If one or a few people leave a room, the level of $CO_2$ will proportionally decrease. Measurement of $CO_2$ is easy and instruments are available to measure it within the enclosed space.

Demand Control Ventilation (DCV) attempts to control the amount of outside air used based on the number of occupants in a given zone, which in turn is established by the indoor $CO_2$ concentration. The method currently available on the HVAC market is based on sensing the rise in $CO_2$ in the indoor air relative to that outdoors. Experience and field studies have shown that the level of $CO_2$ in a room is a reliable indicator of the air quality and ventilation rate, and could therefore be used as the determing parameter in DCV systems. $CO_2$ works because the rate at which it is generated indoors is somewhat proportional to the number of occupants, assuming no significant additional sources of $CO_2$ are present.

If, $CO_2$ levels in a room are higher than 1000ppm, then it is an indication that not enough outdoor air is coming in to dilute the $CO_2$ level. A low level of $CO_2$ (<600ppm) indicates lower number of people and suggests that the ventilation rate could be turned down.

Ventilation systems alone can't mitigate IAQ problems. Outside air:–

- Can bring in pollutants from outside;
- Can be the source of pollutants inside;
- Can cause pollutants to flow from one location in a building to another or
- Can fail to dilute or remove pollutants from a building or a portion of it.

When all these factors add up, the single biggest cause of IAQ emerges as – improperly designed, installed, operated or maintained ventilation systems.

Increased awareness of the importance of IAQ has resulted in "alternative" technologies being offered for achieving IAQ. Filtration and Ozone Generators have resultantly been highlighted.

**OZONE ENRICHMENT**

Ozone enrichment of indoor air is being suggested by vendors as a method of cleaning indoor air. It is claimed that ozone reacts with the pollutants rapidly, results in rapid oxidation leaving carbon dioxide and moisture. When it encounters chemical pollutants, it almost instantly oxidizes them and keeps the indoor air free of chemical pollutants. Manufacturers and vendors of ozone air purification devices often use misleading terms to describe ozone. Terms such as "energized oxygen" or "pure air" suggest that ozone is a healthy kind of oxygen.

However, its use has generated some discussion due to the toxic nature of this gas and concerns regarding its harmful effects on health on exposure. The same chemical properties that allow high concentrations of ozone to react with organic material outside the body give it the ability to react with similar organic material that makes up the body, and potentially cause harmful health consequences.

In the following section we will discuss the myths and realities of using Ozone as method of cleaning the air and improving IAQ. The objective of this course is to provide accurate

information regarding the use of ozone-generating devices in indoor occupied spaces. This information is based on the the most credible scientific evidence currently available.

## SECTION - 2 OZONE – MYTHS & REALITIES

### What is Ozone?

Ozone is a colorless gas, discovered accidentally in 1785 by a German scientist, and named after the Greek word 'ozein', meaning 'to smell'. It is seldom produced in nature, except during lightning. It is represented by the chemical formula $O_3$ having 3 atoms of oxygen. It has a molecular weight of 48 and is 1.6 times heavier than air, with specific weight of 8.9 cu-ft per lb.

At low concentrations, it has a very distinct sweet and pleasant odor – which has at times been referred to as the smell of ‘fresh, clean air’ as ‘in the mountains’ and ‘near waterfalls’, or ‘after a thunderstorm or lightning’. Natural ozone concentration at ground level can vary between 0.01 – 0.05ppm.

Ozone is the second most powerful oxidizing agent second only to Fluorine. Ozone is 52% more powerful than gaseous chlorine in terms of its oxidizing potential and works at killing bacteria more than 1,000 times faster than chlorine. [Note that the Fluorine finds very limited use in practice, being rare and expensive halogen gas and is linked to many devastating side effects and complications for routine human applications].

### What are the advantages of using Ozone?

1. Over 50 % more efficient at breaking through bacteria membranes compared to chlorine;
2. Kills a wide range of bacteria over 3000 times faster than chlorine;
3. Potent disinfectant at low concentrations;
4. Decomposes into oxygen gas leaving no by-products;
5. FDA-approved for direct contact with food;
6. Extends shelf-life of most food products;
7. Potent odor, taste and color remover;
8. Easily and economically produced at point of use;
9. Easily detectable at low concentrations by humans, thereby safe to manage;

10. Regulatory framework in place for human exposure in most countries.

**How does Ozone purifies air?**

Here's how the process works:

1. Oxygen molecules ($O^1$ and $O^2$) are converted to ozone ($O^3$) by either a high-voltage electrical charge (such as from lightning), or by ultraviolet light.
2. One oxygen atom ($O^1$) splits off from the ozone molecule, and reacts with other particles when it comes within range of a particle and/or pollutant. Ozone is highly reactive, so it never fails to initiate this reaction with other particles.
3. As the 2nd most powerful oxidant in existence, the single oxygen atom proceeds to "oxidize" the particle it reacts with. This means it burns the particle, which changes its physical properties. As a result, the particle will no longer be able to reproduce if it is biological. In other words, the particle becomes completely harmless.
4. When the single oxygen ($O^1$) molecule oxidizes the particle, it too is destroyed. This leaves behind the $O^2$ it split away from, or pure and clean oxygen.

**How is Ozone Produced?**

Ozone can be produced several ways, although one method, corona discharge, predominates in the ozone generation industry. Dried air or oxygen is passed through an electrified field (corona) generated by a high voltage between positive and negative grids separated by a dielectric and a discharge gap. The high voltage splits the molecular oxygen into atomic oxygen. Some of the atomic oxygen merges with molecular oxygen to form ozone, while other oxygen atoms simply recombine to form $O_2$.

The voltage required to produce ozone by corona discharge is proportional to the pressure of the source gas in the generator and the width of the discharge gap. Theoretically, the highest yield (ozone produced per unit area of dielectric) would result from a high voltage, a high frequency, a large dielectric constant, and a thin dielectric. However, there are practical limitations to these parameters. As the voltage increases, the electrodes and dielectric materials are more subject to failure. Operating at higher frequencies produces higher concentrations of ozone and more heat requiring increased cooling to prevent ozone decomposition. Thin dielectrics are more susceptible to

puncturing during maintenance. The design of any commercial generator requires a balance of ozone yield with operational reliability and reduced maintenance. When ambient air is used as a feed gas, you can get ozone between 1 and 2 percent by weight in air. When oxygen is used as a feed gas, you can get ozone between 6 and 12 percent by weight.

Ozone can also be produced by irradiating an oxygen-containing gas with ultraviolet light and electrolytic reaction. Air is passed through a chamber between the UV lamp and a shield. UV light can create or destroy ozone depending on the UV wavelength. Wavelengths of 185 nanometers (nm) are required for the generation of ozone and 254 nm for the destruction of ozone. This method produces a very low level of ozone and is usually suitable for small applications.

In addition to these methods, ozone may also be made through electrolytic and chemical reactions.

**Note -** Because Ozone is an unstable molecule, it cannot be stored in any form. Ozone has a short half-life* and will decay soon when produced. Therefore, it should be produced locally at site, and consumed immediately.

**Ozone Half Life* - The half life of ozone in water is about 30 minutes, which means that every half hour the ozone concentration will be reduced to half its initial concentration. For example, when you have 8 g/l, the concentration reduces every 30 minutes as follows: 8; 4; 2; 1; etc. Ozone's half life in air at room temperature of 75°F is no more than 10 minutes.

**What are the potential risks of experiencing high concentration of Ozone?**

Ozone is toxic to inhale.

Exposure to ozone can make breathing difficult, inflame the lungs and lining of the respiratory tract, lead to permanent lung damage, and make it harder for the body to fight respiratory diseases. Symptoms to watch for include coughing, shortness of breath, and chest tightness/chest pain. In asthmatics, it can trigger asthma attacks and worsen symptoms. In people already in poor health, repeated exposure to high levels of ozone can increase the risk of dying.

**Which health standards organizations provide information on the use of Ozone?**

Ozone is a toxic gas with vastly different chemical and toxicological properties from oxygen.

Several federal agencies have established health standards or recommendations to limit human exposure to ozone. These exposure limits are summarized below:

Ozone levels from 0.3ppm irritate the respiratory tract and the mucous membranes of the eye, while levels of around 100ppm are dangerously toxic within a few minutes.

- The Food and Drug Administration (FDA) requires ozone output of indoor medical devices to be no more than **0.05**ppm. [*This level is equal to a stage one smog alert when local air pollution control districts advise the public to avoid some outdoor activities].*
- The Occupational Safety and Health Administration (OSHA) require that workers not be exposed to an average concentration of more than **0.10**ppm (0.2 mg/$m^3$), for 8 hours.
- The National Institute of Occupational Safety and Health (NIOSH) recommend an upper limit of **0.10**ppm, not to be exceeded at any time.
- Environment Protection Agency's (EPA's) National Ambient Air Quality Standard for ozone is a maximum 8 hour average outdoor concentration of **0.08**ppm.

Other agencies that have established health standards and recommendations to limit human exposure to ozone are:

- Indoor Air Quality Association (IAQA) - **0.05**ppm
- World Health Organization (WHO) - **0.05**ppm
- ASHRAE (American Society of Heating, Refrigerating and Air conditioning Engineers) - **0.05**ppm
- The Swedish National Board of Occupational Safety and Health has drawn up hygienic limit values (acceptable average levels in inhaled air) for ozone. Two main levels are used:

- Level limit value (LLV): Highest acceptable average content in inhaled air during 8 hours.
- Ceiling limit value (CLV): Highest acceptable average content in inhaled air during 15 minutes

The acceptable LLV is **0.1**ppm (0.2 mg/$m^3$) and the CLV is **0.3**ppm (0.6 mg/$m^3$).

## OZONE – MYTHS AND REALITIES

With public concern about indoor air quality rising, advertising and sales of Ozone Generators is increasing. Manufacturers often falsely claim that these devices eliminate bacteria, mold, and chemical contaminants from the air, and that they help persons with asthma and allergies. Vendors of ozone generators or air purifier devices generating ozone sometimes use words like "activated oxygen," "super oxygen," "trivalent oxygen," "allotropic oxygen," "saturated oxygen," "mountain-fresh air," or "energized oxygen" when talking about ozone. These words give readers a false picture, by implying that ozone is a "healthy kind of oxygen." **This is untrue**.

Independent studies by the Environmental Protection Agency (EPA), and others have shown that these devices do not effectively destroy microbes, remove odor sources, or reduce indoor pollutants within the allowable permissible concentration of ozone. Although ozone is used effectively in water to destroy microbes, ozone in air must reach extremely hazardous levels to effectively kill microbes.

This section attempts to address the common vendor claims and 13 myths associated with deliberate release of ozone in indoor spaces.

**MYTH # 1**

**OZONE IS MOST EFFECTIVE IN CONTROLLING INDOOR AIR POLLUTION**

**Vendors Claim:**

Ozone removes practically all airborne pollutant from the air and is very effective in controlling indoor air pollution not only in large buildings with closed circuit air conditioning, but also in small offices and residences. Normally air conditioning ducting

breeds mold and fungi and can harbor other bacteria as well due to the presence of moisture. Ozone helps in eliminating microorganisms from the ducts. If sufficient ozone is made available, it will render almost every airborne chemical contaminant harmless and transform polluted air to pure and refreshing air.

**Reality:**

This is misleading.

Although, ozone is the most powerful oxidizing agent commercially available, available scientific evidence shows that at concentrations that do not exceed public health standards, ozone has little potential to remove particles (dust and pollen) from the air, nor do they kill bacteria, viruses, mold, or other biological contaminants. A study by the U.S. Environmental Protection Agency indicated that ozone concentrations would have to be 5 - 10 times higher than what public health standards allow before the ozone could decontaminate the air sufficiently to prevent survival and regeneration of the organisms, once the ozone is removed. Even at high concentrations, ozone may have no effect on biological contaminants embedded inside of porous materials such as carpet fibers, furniture cushions, duct lining or ceiling tiles. A review of EPA findings indicate that, for many of the chemicals commonly found in indoor environments, the reaction process with ozone may take months or years.

**MYTH # 2**

**OZONE DOES NOT LEAVE ANY HARMFUL BY-PRODUCT OR RESIDUE**

**Vendors Claim:**

Ozone doesn't leave any residues or by-product. Ozone in process of reaction oxidizes and reverts back to oxygen. For example carbon monoxide (CO), a very harmful compound is oxidized to $CO + O_3 = CO_2 + O_2$ and formaldehyde, a carcinogenic compound is oxidized as $2(CHOH) + 2O_3 = 2H_2O + 2CO_2 + O_2$.

All of the by-products are mostly environmentally friendly and far less harmful to humans than the original compounds.

**Reality:**

Contrary to specific claims by vendors, ozone generators are not effective in removing carbon monoxide or formaldehyde. In fact it increases chemical air pollution by combining with compounds typically found in ordinary household cleaners, plug-in type air fresheners, and personal hygiene products. Many of these products contain a class of volatile organic compounds (VOCs) called terpenes, which are the fragrance component of pine and citrus oils. Ozone combines with terpenes to form dangerous reaction products (including formaldehyde, [a known human carcinogen and respiratory tract irritant]) which may be even more irritating than the parent chemicals.

Ozone's effectiveness to oxidize chemical air pollutants "to leave only carbon dioxide, water, and breathable oxygen" is NOT proven. A number of independent studies have concluded that ozone may react with other building materials to produce secondary outgassing products which are also irritants or potentially unsafe.

**MYTH # 3**

**OZONE DESTROYS THE SENSE OF SMELL**

**Vendors Claim:**

Ozone is an effective deodorizer and it chemically alters the noxious chemicals by oxidizing molecules of carbon, hydrogen, sulfur and nitrogen to odor-free molecules like carbon dioxide and water.

Ozone eliminates all kinds of odor including tobacco smoke and odors from pets, cooking, mold, mildew and other household sources. Ozone in residential and commercial applications maintains the upholstery in fresh mint condition and avoids development of musty smell over a period of time. Ozone in hotel guest rooms removes the food, tobacco and alcohol smell making the air feel cleaner to breathe. Ozonising restaurant keeps the food smell from permeating into the neighboring area. Ozonised bars feel fresh with reduced tobacco smoke and alcohol smell. Similarly the lobby area can also be ozonised along with the banquet halls and conference rooms; all smelling fresh.

**Reality:**

This is misleading.

Ozone is not effective in removing odor, but instead, can deaden the sense of smell. Being unable to detect odor removes our natural warning property for exposure to high levels of ozone. Elevated ozone levels react with the chemicals present in synthetic carpets, foams, furniture covers, garments, rubber pads and other household items; producing increased concentration of formaldehyde, formic acid and other ultra-fine particulate matter. If produced in sufficient amounts, these by-products are distinctly odorous and have compounding negative health effects.

*Per ASHRAE, 1989, ozone is not considered useful for odor removal in building ventilation systems.*

**MYTH # 4**

**OZONE CAN BE USED EFFECTIVELY IN BOTH OCCUPIED AND UNOCCUPIED SPACES**

**Vendors Claim:**

Ozone can be used in both Occupied and Unoccupied Spaces

**Reality:**

Use of ozone for air treatment is NOT recommended if people are around.

Ozone is a toxic gas with vastly different chemical and toxicological properties from oxygen. The properties that allow high concentrations of ozone to react with organic material outside the body give it the ability to react with similar organic material that makes up the body, and potentially cause harmful health consequences. When inhaled, ozone can damage the lungs. Relatively low amounts can cause chest pain, coughing, shortness of breath, and, throat irritation. Ozone may also worsen chronic respiratory diseases such as asthma and compromise the ability of the body to fight respiratory infections. People vary widely in their susceptibility to ozone. Healthy people, as well as those with respiratory difficulty, can experience breathing problems when exposed to ozone. Exercise during exposure to ozone causes a greater amount of ozone to be inhaled, and increases the risk of harmful respiratory effects. Recovery from the harmful effects can occur following short-term exposure to low levels of ozone, but health effects may become more damaging and recovery less certain at higher levels or from longer

exposures (US EPA, 1996a and 1996b). Several federal agencies have established health standards to limit human exposure to not more than 0.1ppm over an 8-hr day, and do not exceed that value by more than a factor of 2 or 3 during the exposure.

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. Ozone can adversely affect indoor plants, and damage materials such as rubber, electrical wire coatings, and fabrics and art work containing susceptible dyes and pigments (U.S. EPA, 1996a).

**Caution -** When the ozone is used in unoccupied areas, make sure the ozone generators are shut off an hour or so prior to reoccupying the space. This idle time is important for ozone to safely dissipate back into oxygen.

**MYTH # 5**

**OZONE CONCENTRATION IN SPACE NEVER EXCEEDS DESIGN VALUES**

**Vendors Claim:**

Ozone is unstable gas that rapidly oxidizes airborne pollutants. If not consumed by pollutants, ozone quickly reverts back to pure and refreshing air. Hence, when the system is well designed for a given space, it is nearly not possible to build up a high level of ozone.

**Reality:**

This is NOT true. The vendor recommendations about appropriate ozone generator sizes for particular spaces are rarely precise to guarantee ozone concentrations below safe permissible public health limits.

Many factors affect ozone concentrations including the amount of ozone produced by the machine(s), more powerful device used for smaller space, the size of the indoor space, the amount of material in the room with which ozone reacts, the outdoor ozone concentration, and the amount of ventilation. The proximity of a person to the ozone

generating device can also affect one's exposure. The concentration is highest at the point where the ozone exits from the device, and generally decreases as one move further away. These factors make it difficult to control the ozone concentration in all circumstances.

One study, conducted by the EPA in California, ran an ozone generator in a test home at its maximum setting. When the room's air was sampled, ozone levels were found exceeding 0.3 parts per million (PPM), and an adjacent room's levels exceeded 0.2 PPM. These readings far exceed the EPA's ambient standard for ozone of 0.08ppm averaged over 8 hrs. At the machine's medium setting, even with the home's central fan turned on, ozone levels still exceeded the limits. California outdoor standard for ozone of 0.07ppm averaged over 8 hrs.

**Note -** There are no ozone standards for indoor air, except for FDA standards, which were written for medical devices. The FDA standard is 0.05ppm.

*This level is equal to a stage one smog alert when local air pollution control districts advise the public to avoid some outdoor activities.*

**MYTH # 6**

**CONTROLLING OZONE GENERATOR OUTPUT IS SAFE AND SIMPLE**

**Vendors Claim:**

Ozone generators typically provide a control setting by which the ozone output can be adjusted. All these devices are microprocessor based that can be controlled precisely upon input signals from ozone sensors. Multiple ozone sensors can be incorporated in the space to turn the generator "on and off" while maintaining ozone concentrations below health standards. Vendors claim that the ozone output of these devices is proportional to the control setting and the effectiveness and reliability of the generator and sensors is proven and established by EPA.

**Reality:**

This is NOT true.

It is difficult to control ozone exposure with an Ozone Generator. The output of ozone generating devices is usually **NOT** proportional to the control setting i.e. a setting at medium does not necessarily generate an ozone level that is halfway between the levels at low and high. The relationship between the control setting and the output varies considerably among devices, although most appear to elevate the ozone output much more than one would expect as the control setting is increased from low to high. In experiments to date, the high setting in some devices generated 10 times the level obtained at the medium setting (US EPA, 1995).

In addition to adjusting the control setting to the size of the room, users have sometimes been advised by vendors to lower the ozone setting, if they smell the ozone. Unfortunately, the ability to detect ozone by smell varies considerably from person to person, and one's ability to smell ozone rapidly deteriorates in the presence of other odors. While the smell of ozone may indicate that the concentration is too high, lack of odor does not guarantee that levels are safe.

Attempting to control ozone generator with digital sensor can give false readings, especially if the area is large. Just because the "average" conditions are satisfied doesn't meet anything; there can still be pockets of high concentration of ozone in under-ventilated areas. The ozone sensors reliability, sensitivity and accuracy itself is a big question. EPA is currently evaluating the effectiveness and reliability of the ozone sensors, and plans to conduct further research to improve society's understanding of ozone chemistry indoors.

**MYTH # 7**

**OZONE GENERATORS ARE APPROVED & NOTIFIED BY FEDERAL AGENCIES**

**Vendors Claim:**

Most vendor state that use of ozone generation equipment and devices has been approved by the federal government and other notified bodies such as US EPA, FDA, OSHA, ASHRAE and ACGIH.

**Reality:**

NO agency of the federal government has approved these devices for use in occupied spaces. In fact several federal government agencies are working to inform public about the risks associated with the use of ozone as air cleaning agent. Evaluations of household air cleaners have been published by the American Lung Association (ALA) and U.S. Environmental Protection Agency (EPA). Both these organizations give explicit warnings against ozone-generating devices. Here is what these organizations say:

1. **The American Lung Association -** Recommends people seeking cleaner indoor air to avoid ozone-generating devices. It suggests the consumers to determine whether any electronic air cleaner they are considering for purchase has been tested for ozone production. Filters and electrostatic precipitators may be safer methods for cleaning air, and are more effective alternatives than ozone generating devices.
2. **The Environment Protection Agency (EPA) -** EPA has come out with a detailed document on this matter being widely circulated among public. Per US EPA, 1996a, 1996b, ozone may worsen chronic respiratory diseases such as asthma and compromise the ability of the body to fight respiratory infections. People vary widely in their susceptibility to ozone. Healthy people, as well as those with respiratory difficulty, can experience breathing problems when exposed to ozone. Exercise during exposure to ozone causes a greater amount of ozone to be inhaled, and increases the risk of harmful respiratory effects. Recovery from the harmful effects can occur following short-term exposure to low levels of ozone, but health effects may become more damaging and recovery less certain at higher levels or from longer exposures (US EPA, 1996a, and 1996b).
3. **California Air Resources Board (ARB)** – The Air Resources Board (ARB) is a department of the California Environmental Protection Agency whose mission is to promote and protect public health, welfare, and ecological resources through effective reduction of air pollutants while recognizing and considering effects on the economy. Per ARB, the ozone generators and other air purifying machines generating ozone are insidious. ARB scientists expressed concern, since some manufacturers aggressively market these products to individuals with asthma and other respiratory and health problems. Ozone can damage the cells lining nasal passages and lungs making it difficult to breathe and can exacerbate asthma

symptoms. The California Department of Health Services (DHS) issued a warning about ozone air cleaning devices in April 1997. *Information on California DHS' Indoor Air Quality Program can be found at the web site: http://www.cal-iaq.org.*

**Recent Actions by Other Organizations having Jurisdiction**

In recent years, Minnesota, North Carolina, and Florida have taken a variety of actions to prevent public health hazards from ozone generators in their states. On December 30, 1997, the Federal Trade Commission (FTC) filed suit against the industry's leading manufacturer (Alpine Industries, Inc.) for violating their 1995 consent order with FTC. The 1995 order required that ozone generator manufacturers halt their practice of making unsupported, misleading health claims about the ability of their products to remove indoor air pollutants and prevent or relieve allergies, asthma and other conditions. In addition, the manufacturers had been required to stop making unsupported claims that their devices are more effective than other air cleaning methods and that they do not create harmful by-products. The current FTC action alleges that Alpine Industries has continued these practices. Related complaints can be directed to the FTC.

Many other international organizations have been issuing warnings about the adverse effects of ozone on human health. Some examples are given below.

**Health Canada, Ottawa –** A risk evaluation by Health Canada on ozone generators in January 1999 concluded that ozone generators pose a risk to the health and safety of the public. The direct and purposeful introduction of ozone into occupied indoor environments is unacceptable and therefore should be avoided. Health Canada is concerned with the adverse health effects that may result from the deliberate exposure of the public to ozone from air cleaners that intentionally generate ozone gas (ozone generators). Ozone is an irritant gas that can cause coughs, chest discomfort, and irritation of the nose, throat, and trachea. Health Canada has received complaints from consumers of respiratory problems when using an ozone generator.

Following a review of current information and in consultation with Health Canada and others, the Canadian Standards Association (CSA) recently made the decision not to certify these products for household use and have issued new interim requirements for

commercial units. This warning is aimed at addressing the devices previously certified and sold. Health Canada has advised public at large, not to use air cleaners designed to intentionally generate ozone (ozone generators) in their homes. It further advises all owners of ozone generators to stop using them in their homes.

**Bangkok Post, Sept 08, 2001 -** Ozonic fined for false claims… Krasae Chanawong, PM's Office minister and Chairman of the consumer agency told that the advertisement for ozonic would be banned and the product's manufacturer fined 50,000 baht for publicizing misinformation. He said the ad incorrectly claimed the product could combat allergies, kill bacteria and viruses and clean formalin-tainted vegetables, seafood, and fruits.

**Why are then ozone generators still on the market?**

While a handful of state and federal agencies have taken actions in an attempt to address this health issue, no agency has clear authority to control ozone emissions from air cleaning/purifying devices, and actions to date have not been effective in addressing this problem.

**MYTH # 8**

**OZONE IS EQUALLY GOOD FOR AIR AND WATER POLLUTION CONTROL**

**Vendors Claim:**

Ozone is the most powerful oxidizer on the earth that could kill microorganisms effectively both in air and water.

**Reality:**

Ozone is often used in water purification to kill microbes and for cooling water treatment in industrial applications. This is because the water chemistry is quite different from air chemistry and secondly even with high concentrations of ozone in water, people are not generally exposed.

The concentration of ozone would have to greatly exceed health standards to effectively neutralize most indoor air contaminants. In the process of reacting with chemicals

indoors, ozone can produce other chemicals that themselves can be irritating and corrosive.

**MYTH # 9**

**OZONE IS MOST SUITABLE FOR HEALTHCARE DISINFECTION**

**Vendors Claim:**

In the area of public health, ozone technology has been a potential source for reducing the role of infection. In health clubs it is vitally important to keep the air fresh and well oxygenated with ozone while reducing the bacterial contamination bred by the perspiring bodies. In hospitals, ozone keeps the air borne contaminants in check from spreading from one patient to another. Its deodorizing effect reduces the 'hospital smell' from the constant use of disinfectants. This makes the hospital more patients friendly.

Ozone is a deterrent to many small insects like mosquitoes and flies. Hence this menace is reduced even in cafeterias and food serving facilities.

**Reality:**

In high concentrations, ozone is a powerful, broad-spectrum antimicrobial agent that has been found to be effective against bacteria, fungi, viruses, protozoa, bacterial and fungal spores. However for safety reasons, the ozone disinfection shall only be conducted in unoccupied room so that ozone toxicity to human is not a concern. When dispersed as an aerial disinfectant, no person should enter the room until the level of residual ozone is below 0.02ppm. In general, ozone concentration drops to below 0.02ppm in an hour after ozonation, therefore people should wait for at least one hour (after turning off the generator) before entering the "ozonated" room.

Available scientific evidence shows that ozone is a much stronger oxidizer than other common disinfectants methods described below and it has some strong benefits.

**Ozone when compared to common disinfection methods:**

Ultraviolet Rays: The most common air disinfection method is using ultraviolet (UV) radiation. UV radiation (UV-C) kills bacteria and viruses by damaging the DNA/RNA of the cells of microorganisms. However, UV radiation could only disinfect air close to the

lamps as UV light has limited penetration capacity. UV disinfection alone may not be adequate to provide virus-free environment.

HEPA Filtration: High Efficiency Particulate Air (HEPA) filter can capture particulate sizes down to 0.3 microns at 99.97% efficiency. HEPA filters can trap most of the bacteria with size larger than 0.3 but these are ineffective removing viruses, which are nanometer ($10^{-9}$ m) in size. Also, air must pass through the filter in order for it to be cleaned. Hence HEPA filters can only clean air that is within a short distance of the HEPA unit.

Chemical Disinfectants: Chemical disinfectants such as chlorine or hypochlorite could also be used for air disinfection, usually by means of vaporizing or spraying. However, these chemical disinfectants are usually difficult to decompose, leaving toxic chemical residues that are hazardous to human health. The usage of chlorine or hypochlorite in many countries has been decreased significantly due to the possibility formation of carcinogenic by-products such as trihalomethanes (THM) during the disinfection process.

Ozone: Ozone kills microorganisms on contact by cellularlysis and cytoplasm dispersion - it directly ruptures the cell walls of the microorganisms, which results in an instantaneous death. By comparison, chlorine kills bacteria by diffusing through the cell wall and then oxidizing the enzymes within the cell. In contrast to chlorine, ozone disinfection does not produce any harmful residues and is considered as an environmentally friendly disinfectant. This makes it ideal for use in medical applications, for example in hospitals or doctors waiting rooms.

The main advantage of ozone compared to other treatment methods for air disinfection is that it is able to efficiently disinfect a large air volume. In contrast to UV radiation and HEPA filter, ozone is a gas that could penetrate to every corners of the room, thus it could disinfect the entire room effectively. Given the advantages of strong oxidizing power, good penetration capacity and no harmful residues left after the treatment, ozone may be recommended to be used in disinfection of contaminated environments. As of June 2001, ozone has gained FDA approval as a sanitizer not only for food contact surfaces but also for direct application on food.

**Caution -** Excessive high concentration ozone should be avoided and the lowest ozone concentration that could kill most of the microorganisms should be selected as optimum. Depends on the contamination level, 0.5 – 2.5ppm ozone level is adequate for air disinfection.

**MYTH # 10**

**OZONE WORKS BETTER THAN AIR FILTERS**

**Vendors Claim:**

Ozone works better than air filters. Performance of air cleaning filters depend on the frequency of passage of air over it, which typically in HVAC systems is about 15 minutes (assuming total air change of 4 per hour). This also implies the pollutant is present in the space for period of 15 minutes, before it is captured by the filter. This is fairly long period of time for pollutant to cause sufficient harm. In ozone system, ozone is present in low concentration in the space at all times. This reacts with pollutant in a very brief period of time, and thus prevents its build up.

**Reality:**

Ozone does not remove particles (e.g., dust and pollen) from the air. The **National Air Filtration Association (NAFA)** supports the position stated by the Environmental Protection Agency that, "...Ozone can be harmful to health," NAFA opposes the use of ozone producing equipment used as air cleaners or air purifiers in occupied spaces. Therefore, NAFA adopts the position that ozone air cleaner manufacturers or ozone air cleaner distributors not be allowed into NAFA membership, unless or until they cease the marketing of these types of products as air cleaners in occupied spaces. This however does not preclude membership to those who sell these devices for use in unoccupied spaces.

**MYTH # 11**

**LOW-LEVEL NATURAL OZONE IS GOOD**

**Vendors Claim:**

Vendors claim that the quality of air in areas such as forests, mountains, urban areas outside of the congestion of the major cities is excellent because of natural concentration of ozone. Therefore with same logic, the levels of ozone can be created artificially in your home to purify your air. Many environmental experts would try to convince you that any ozone in your home may be potentially dangerous but this is far from the truth. The use of ozone to purify the air in your home has wonderful benefits of achieving indoor air quality.

Vendors say that Ozone is not Smog. The offensive odors, burning eyes and aggravated respiratory problems associated with smog (air pollution), are NOT attributed to high levels of ozone in common polluted air. People mistake hydrocarbons, oxides of carbon, sulfur and nitrogen, halogenated by-products, lead and other sulfur compounds – all these irritants and more – for a single scapegoat: ozone.

**Reality:**

While it is true that the quality of air in areas such as forests, mountains, urban areas outside of the congestion of the major cities is excellent, this is due to the fact that the measureable level of ozone in these areas is closer to a safe level of .02-.03ppm of ozone. In cities, the harmful concentrations of ozone in the atmosphere are often accompanied by high concentrations of other pollutants, including nitrogen dioxide, fine particles, and hydrocarbons. Also harmful levels of ozone can be produced by the interaction of sunlight and certain chemicals emitted to the environment (e.g., automobile emissions and chemical emissions of industrial plants). Whether pure or mixed with other chemicals, ozone can be harmful to health.

**MYTH # 12**

**WORLD IS CONCERNED ABOUT OZONE DEPLETION**

**Vendors Claim:**

Ozone is very important compound for maintaining air quality and the Montreal Protocol – the landmark international treaty signed in year 1987 focuses on saving the Earth's ozone layer by calling nations to reduce these emissions.

**Reality:**

The “high in the sky” ozone should not be confused with the harmful “low to the ground” ozone. The phrase "good up high – bad nearby" has been used by the U.S. Environmental Protection Agency (EPA) to make the distinction between ozone in the upper and lower atmosphere. Ozone found high up in the atmosphere, called “stratospheric ozone”; 15-40 km above earth surface, helps filter out damaging ultraviolet radiation from the sun. The ozone layer acts like a giant sunshade, protecting plants and animals from much of the sun's harmful ultraviolet radiation.

But the ozone in the air we breathe – can be harmful to the respiratory system. "Bad" ozone is formed when the carbon dioxide given off by cars and power plants react with sunlight. Those chemicals are a mixture of nitrogen oxides (NOx), volatile organic compounds (VOC's), methane ($CH_4$) and carbon monoxide (CO). The result is smog - the air pollution that we see and smell. While it is true that ozone is not smog, but most ground level ozone is a major component of smog. This is the reason that ozone has long been used as an indicator of smog conditions.

What is Montreal Protocol?

The Montreal Protocol on Substances That Deplete the Ozone Layer is a landmark international agreement designed to protect the stratospheric ozone layer. The treaty was originally signed in 1987 and substantially amended in 1990 and 1992. The Montreal Protocol stipulates that the production and consumption of compounds that deplete ozone in the stratosphere--chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform--are to be phased out by 2000 (2005 for methyl chloroform). Scientific theory and evidence suggest that, once emitted to the atmosphere, these compounds could significantly deplete the stratospheric ozone layer that shields the planet from damaging UV-B radiation.

**MYTH # 13**

**OZONE CAN REDUCE FRESH AIR INTAKE IN HVAC SYSTEMS & SAVES ENERGY**

**Vendors Claim:**

Vendors claim that the ventilation air quantities could be lowered when considering ozone enrichment. By bringing in lesser outside air, the energy to heat and cool that air will be reduced considerably.

**Reality:**

While it is true that over ventilated buildings waste energy, under ventilated buildings may have significant adverse affects on occupants. ASHRAE 62-1989 standard which is de-facto in U.S. recommends a minimum of 15 CFM of outdoor air per person for offices (reception areas) and 20 CFM per person for general office space with a moderate amount of smoking. Sixty cubic feet per minute per person is recommended for smoking lounges with local mechanical exhaust ventilation and no air recirculation. ASHRAE latest edition 2004, now require maintaining ventilation rate on cfm per-person plus floor area (cfm per sq-ft) basis. Further the ventilation is required not only for dilution of contaminants but also for exhaust and pressurization need of spaces. Changes to ventilation rates therefore cannot be done in a vacuum and it is strongly recommended that a qualified engineer verify the application and design.

**MYTH # 14**

**OZONATION IS SIMILAR TO $CO_2$ BASED DEMAND CONTROL VENTILATION**

**Vendors Claim:**

Vendors interpret that the dynamic reset section of ANSI/ASHRAE 62.1-2007 allows designers to use optional controls to reset outdoor air intake flow and/or zone minimum airflow as conditions within the system change. For instance, it would allow a ventilation-system control approach that alters outdoor air intake flow, if volatile organic compounds (VOC) are within permissible limits.

**Reality:**

It is important to note that ANSI/ASHRAE 62.1-2007 interpretation applies specifically to $CO_2$ control. For instance, it would allow a ventilation-system control approach that alters outdoor air intake flow based on time of day, if variations in zone population follow a predictable schedule.

Mixed gas or so-called "VOC sensors" can not be applied using this interpretation because they are non-specific and react to very general changes of gases in the space. They are not specific to occupancy and are best utilized to identify incidence of non-predictable contaminant releases in the space. Because mixed gas sensors are impossible to calibrate and are subject to continuous and unpredictable drift, their best application is for detecting short-term, large-magnitude changes of general gas levels in air. They should never be used to proportionally control ventilation as a $CO_2$ sensor might be used for occupancy.

## CONCLUSIONS AND RECOMMENDATIONS

While pollutants commonly found in indoor air are responsible for many harmful effects, there is considerable uncertainty about what concentrations or periods of exposure are necessary to produce specific health problems. People also react very differently to exposure to indoor air pollutants. Further research is needed to better understand which health effects occur after exposure to the average pollutant concentrations found in homes and which occur from the higher concentrations that occur for short periods of time.

Three strategies (in order of effectiveness) that may be used to reduce indoor air pollutants are source control, ventilation, and air cleaning. Air cleaning may achieve an additional reduction in the levels of certain pollutants when source control and ventilation do not result in acceptable pollutant concentrations. However, air cleaning alone cannot be expected to adequately remove all of the pollutants present in the typical indoor air environment.

Ozone enrichment of indoor air is being suggested as a method of cleaning the air. Whether in its pure form or mixed with other chemicals, ozone can be harmful to health. When inhaled, ozone can damage the lungs. Relatively low amounts of ozone can cause chest pain, coughing, shortness of breath and, throat irritation. It may also worsen chronic respiratory diseases such as asthma as well as compromise the ability of the body to fight respiratory infections. Some studies show that ozone concentrations produced by ozone generators can exceed health standards even when one follows

manufacturer's instructions. Available scientific evidence shows that, at concentrations that do not exceed public health standards, ozone is generally ineffective in controlling indoor air pollution.

In conclusion I would like to stress, let us not ignore these important issues and should **NOT** resort to "Ozone Generators" unless its use is wetted by Federal Agencies. The public is advised to use proven methods of controlling indoor air pollution. These methods include eliminating or controlling pollutant sources, increasing outdoor air ventilation, and using proven methods of air cleaning.

**Annexure -1**

## Ozone - Material Safety Data

| **GENERAL DATA** | |
|---|---|
| Product/material | Ozone |
| Molecular formula | $O_3$ |
| Principal characteristics | Oxidizing gas |
| Molecular weight | 48.0 |
| Production | Corona discharge |
| Concentration | Up to 18 \% by weight in oxygen/oxygen-enriched air |
| Boiling point | -111.0°C |
| Melting point | -192.7°C |
| Solubility in water by weight at 20°C | 003 g/l (3 ppm) |
| Vapor density | 1.6 (1 = air) |
| Appearance and odor | Ozone is colorless at all concentrations. It has a pungent characteristics odor usually associated with electrical sparks. The odor is generally detectable by the human nose at concentrations of 0.02 and 0.05 ppm. |
| Fire/Explosion and | Ozone is a powerful oxidizing agent. Oxidation with ozone |

| | |
|---|---|
| hazard data | evolves more heat and usually ignites at a lower temperature than oxidizing with oxygen. Ozone reacts with non-saturated organic compounds to produce ozonides, which are unstable and may decompose with explosive voilence. Ozone is an unstable gas that, at normal temperatures, decomposes to biatomic oxygen. At elevated temperatures and in presence of certain catalysts such as hydrogen, iron, copper and chromium, this decomposition may be explosive. |
| Flash point | Not applicable |
| Auto ignition temperature | Not applicable |
| Flammability | Non-flammable/vigorously supports combustion |

**REACTION DATA**

| | |
|---|---|
| Conditions contributing to instability | Ozone spontaneously decomposes under all ordinary conditions, so that is not normally encountered except in the immediate vicinity of its production. Decomposition is accelerated by contact with solid surfaces, by contact with chemical substances and by the effect of heat. |
| Incompatibilities | Ozone is a power oxidizing agent and reacts with all oxidizing materials, both organic and inorganic. Some reaction products are highly explosive. |
| Hazardous decomposition products | None |

## HEALTH HAZARD DATA

| | |
|---|---|
| Permissible Exposure Limits | The following limits are widely accepted (USA, UK and other parts of Europe):<br>'8' hour - 8 hour per day/5 days per week (occupational exposure limit) - 0.1 ppm<br>'15 minute (short term exposure limit) - 0.3 ppm |
| Toxicology of ozone | The acute and chronic effects of excessive exposure to ozone have been well investigated. Exposure to concentrations of ozone in excess of several tenths of a ppm sometime cause reports of discomfort in a small susceptible portion of the population. This can be in the form of headaches of dryness of the throat and mucous membranes of the eyes and nose following exposures of short duration. Repeated exposure to ozone at such concentrations at 24-hour intervals, however, caused no further increase in airway irritability. In fact after the first exposures, additional exposures to ozone had progressively lesser effects suggesting that tolerance may develop over time.<br><br>Ozone has been shown to be more injurious at concentrations exceeding 2.0ppm over several hours, such as experienced by gas shielded arc welders. The primary site of acute effects is the lung which is characterized by pulmonary congestion. This acute impact subsided in welders when exposures where reduced to less than 0.2ppm. Based on animal studies, exposure over 10 to 20ppm or an hour or less believed to be lethal in humans although there has never been a single recorded fatality attributed to ozone exposure in more than 100 years of commercial use. (Compare with this experience with Chlorine as which has claimed many victims in peacetime as well as during war).<br><br>With respect to long term or chronic toxicity, ozone is a radiomimetic |

**HEALTH HAZARD DATA**

agent, i.e. the effects of long term exposure to excessive ozone exhibits the same affects as excessive exposure to sunlight. These effects are drying of the dermal surfaces and general ageing of exposed tissues. Ozone is not generally regarded or suspected of being a human carcinogen, neither does in exhibit tertogenic or mutagenic properties.

In the event of an ozone leak

1. Ventilate the area
2. Immediately switch the ozone generator off
3. Stop the flow of ozonated water
4. Where high levels of ozone are experienced (in excess of 0.1ppm) all personnel should vacate the affected area until it has been thoroughly ventilated
5. When ozone levels in excess of 0.3ppm are present, or when personnel are required to work in restricted spaces or tanks, where ozone my be present, only persons wearing suitable breathing apparatus should be allowed in the area and the appropriate safe working practices for confined areas should be applied

| | |
|---|---|
| Disposal of waste ozone gas | It is accepted practice, and required by statute in some jurisdictions, that Ozone gas should not be released into the atmosphere but should be destroyed using an approved ozone destruction method. (Catalytic, thermal, or absorption). |
| Disposal of waste ozone | All potential outlets of ozone gas into the occupied areas or external atmosphere should be identified. |

| **HEALTH HAZARD DATA** | |
|---|---|
| gas | 1. All routine operational releases of ozone to the occupied areas or external atmosphere should be contained and passed through an ozone destruction system (as above)<br>2. All occupied areas where ozone is generated or applied should be provide with an effective ventilation system commensurate with the rate of ozone production and other risk factors<br>3. Suitable masks or breathing apparatus should be readily available for the protection of the personnel in the event of leakage and for protection where working requirements make it impossible to avoid contact with ozone<br>4. Where ozone is applied to liquids It is important to consider that ozone will escape from solutions under most conditions. Precautions include: ensuring that all vessels containing ozonated liquids are air-tight or under negative pressure to prevent escape of ozone. Any vents where ozone might escape should be connected to an ozone destruction system. Where ozonated liquids, such as used rinse water, are discharged this should be via close pipe work to close drains |
| Disposal of waste ozone gas | • Eye exposure - If ozone gets into the eyes, wash immediately with large amount of water, lifting the upper and lower eye lids occasionally. Seek medical attention as soon as possible<br>• Breathing - If a person breath in large amounts of ozone, move the person into warm un-contaminated air at once. If breathing has stopped, perform artificial respiration. When breathing is difficult, properly trained personnel may assist by administering breathing oxygen. Keep the affected person war and at res. Seek medical attention as soon as possible |

**HEALTH HAZARD DATA**

- Rescue - Move the affected person to safety. If the person has been overcome notify somebody else and put into effect the established emergency procedures. Do not enter the affected area without assistance or against the advice of the recommended safety procedures as they may apply at each facility