Application of Ozone in Food Industries

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REVIEW PAPER

Application of Ozone in Food Industries

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ABSTRACT

Ozone is very reactive and unstable gas with a short half - life before it reverts back to oxygen. Ozone is the most powerful and rapid acting oxidizer produced, and will oxide all bacteria, endotoxins, mold and yeast spores, organic material and viruses. New uses are being discovered every day and will be a big part in every one's life in the very near future. If ozone would cease to exist, life on this planet would also cease to exist. Ozone is nature's way of purifying the air we breathe. The use of Ozone on the foods we consume will be the only "natural alternative" to chemicals or gamma radiation to control pathogens and to increase shelf life.

Key words *Ozone, Unstable gas, Natural alternative, Oxidize*

Ozone is naturally occurring component of fresh air. The ultra-violet rays of the sun reaching with the earth's upper atmosphere, which creates a protective ozone layer, can produce it; or it can be created artificially with an ozone generator. The ozone molecules contains three oxygen atoms wheras the oxygen molecule contains only two. Ozone is very reactive and unstable gas with a short half - life before it reverts back to oxygen. Ozone is the most powerful and rapid acting oxidizer produced, and will oxide all bacteria, endotoxins, mold and yeast spores, organic material and viruses.

Chemistry of Ozone

Ozone (O_3), a colorless gas, is the tri-atomic form of oxygen, also known as "Super Oxygen". Some of the oxygen molecules split into two separate oxygen atoms. These single atoms then form semi-unstable bonds with the oxygen molecules. These oxygen molecules are highly reactive. This reactivity is because of the third atom of oxygen; also know as a "Hunger atom". This atom is eager to break away from this semi unstable bond and react with any Oxidizable compound (organic or inorganic). Very short life span half life of ozone (about 20 minutes). Ozone cannot be stored and must be generated on site.

History of Ozone

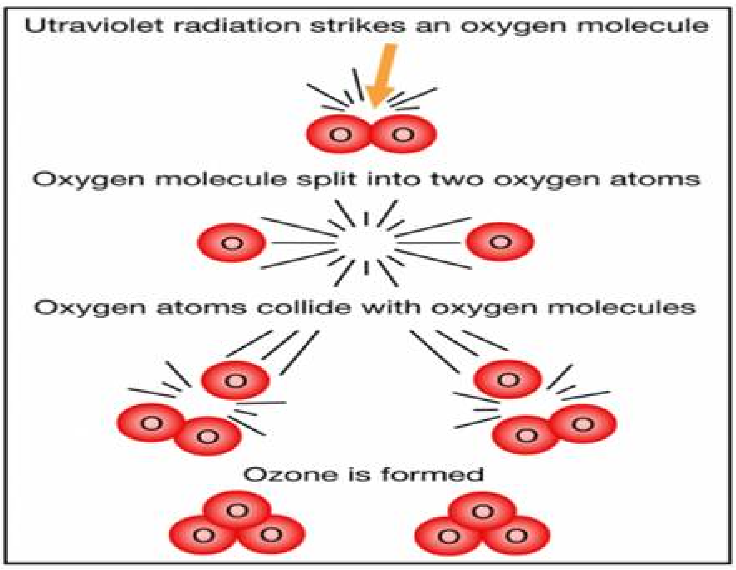
Ozone has played a significant role in the water treatment process in the past and will continue to do so in the future. The utilization of ozone in industrial situations has a long and impressive history, one that pre-dates current environmental concerns. The American Indians, for whom fishing was a central industry, recognized a correlation between a successful catch and a strange odor released by the action of lightning after an electric storm. The explanation for this natural phenomenon is that after an electric storm the upper layer of water in lakes is enriched with diluted oxygen and therefore naturally ozonated. The positive influence of ozone on the digestive system of different species of fish has been scientifically documented. The closed loop for fish farming is only possible with ozone because of its ability to destroy viruses responsible for many diseases in fish culture. The most common use of ozone is for the treatment of water.

1785 - The odor of ozone was first reported by Van Mauren in the vicinity of an Electrical discharge.

1840 - Christian Schonbein identified this odor and named it as "Ozein". In Greek Ozein means, "smell".

1867 - The identity of the structure of the component was confirmed as triatomic oxygen.

1893 - Commercially used when the first full scale drinking water treatment application was implemented.



1906 - Scientists and Doctors studied the ozonation system and constructed a 19,000 m3/day plant using ozonation for disinfection at Nice, France.

Structure & Properties

- Ozone is an allotrope of oxygen consisting of 3 oxygen atoms and its molecular formula is O_3. It is also called as "activated Oxygen".
- Ozone is very reactive in an aqueous environment. It can oxidize material between 10 & 1000 times faster than other oxidants used in water treatment.
- Ozone is relatively unstable. Half-life of ozone in distilled; highly purified water is about 25 minutes at 20° C. In the presence of impurities with which it can react, its half-life is considerably reduced.
- The decomposition product of gaseous ozone is oxygen.
- Gaseous ozone is only sparingly soluble in water about 13 times as soluble as oxygen. Solubility of ozone depends on the water temperature and the ozone concentration in the gas phase.
- Very powerful oxidizing agent. Unique feature of decomposing to harmless, non-toxic, environmentally safe material- oxygen.
- An ozone level of 0.4 ppm for 4 minutes has been shown to kill any bacteria, virus, mould and fungus

Property	**Ozone**	**vs. Oxygen**
Molecular Formula:	O_3	O_2
Molecular Weight:	48	32
Color:	light blue	colorless
Smell:	- clothes after being outside on clothesline -photocopy machines -smell after lightning storms	- odorless
Solubility in Water (@ 0°C):	0.64	0.049
Density (g/l):	2.144	1.429
Electrochemical Potential, V:	2.07	1.23

Formation of Ozone

An electrical discharge splits the oxygen molecule into two oxygen atoms. These unstable oxygen atoms have excess electrons and combine with other oxygen molecules to lower their energy state. This combination forms ozone. Ozone is also unstable and reacts with other gases changing their molecular structure.

Mechanisms ozone destruction of the target organisms

Ozone oxidizes sulfhydryl groups and amino acids of enzymes, and microbe's increases permeability. Which weakens the cell wall and leads to cell rupture, leading to almost immediate death of the cell caused by release of cellular material into the external environment. Peptides and Proteins to shorter peptides. (Victorin.1992).

Ozone destruction of bacteria is accomplished by attack on the bacterial membrane Glyco-proteins and /or Glyco-lipids. In case of gram –ve bacteria,

The lipoprotein and lipo-polysaccharide layers are the first sites of destruction resulting in increases in cell permeability. The extra atom of oxygen consumes odors, dirt and pesticides, completely by oxidation reactions (Zeynep *et al.*, 2003).

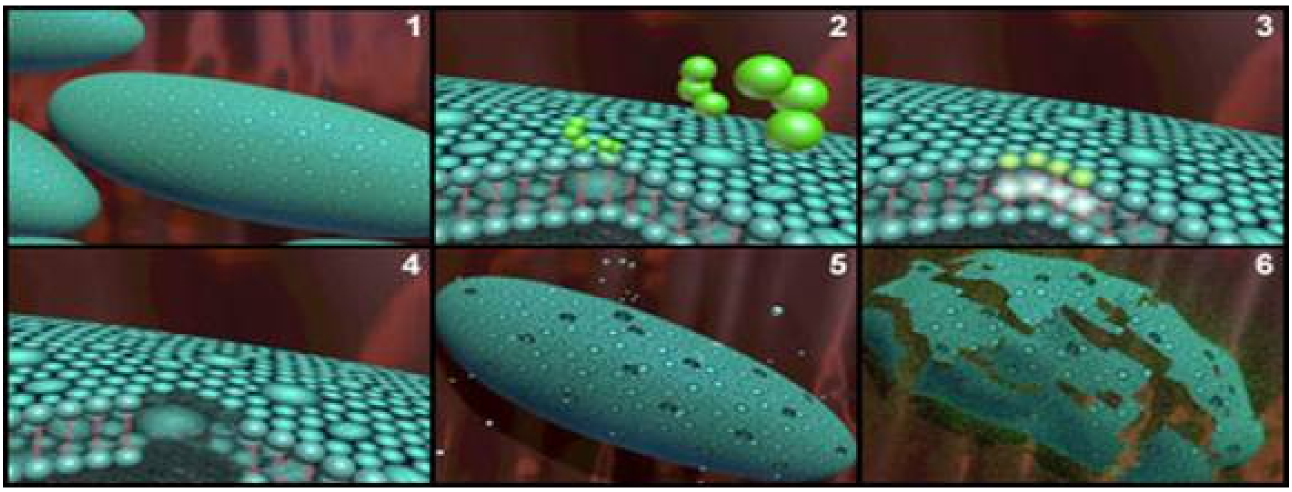
Ozone Generation Methods

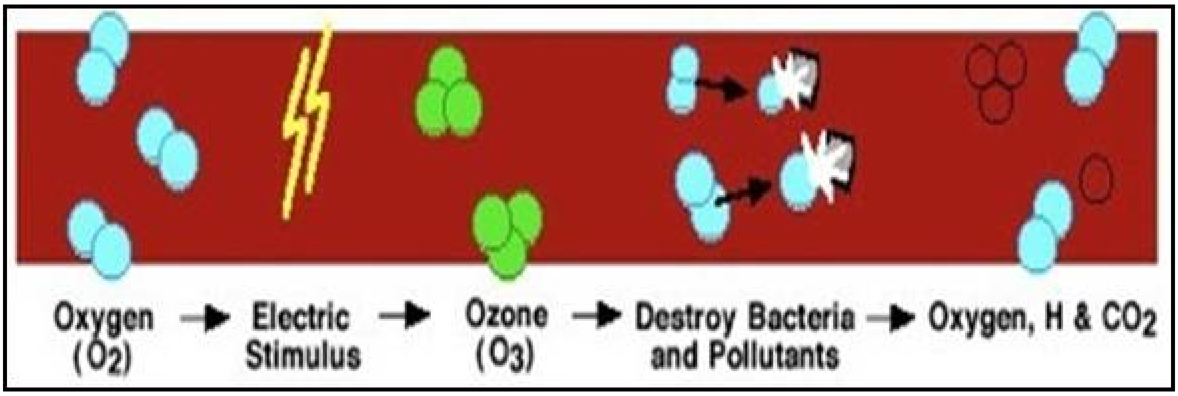
Ozone is unstable hence it can be generated in site wherever needed. There are four methods of ozone generation. They are

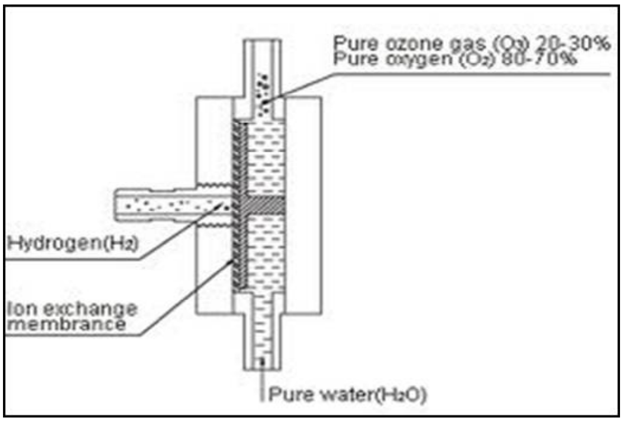
1. Electrolytical method
2. Radiochemical method.
3. photochemical method
4. electrical discharge method

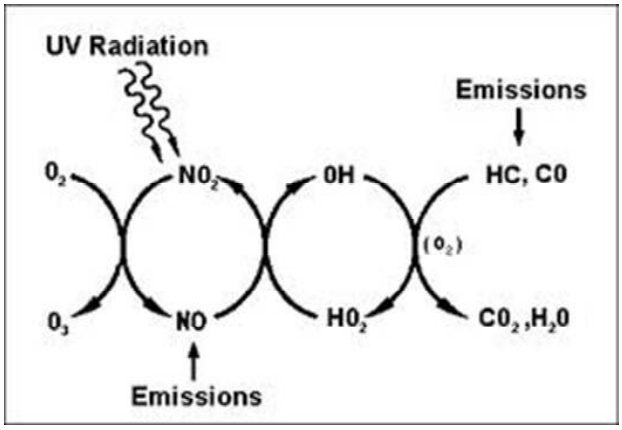
Electrolytical method: Electrolysis of an acid

This is very easy way to produce ozone with very simple equipment. It could have great appeal in unsophisticated and remote locations, but is a seldom used method of producing ozone for drinking water treatment. At present, this process is probably 2 to 5 times more expensive than corona discharge method. It also involves transporting acids to sites of ozone production, and potentially problematic disposal of containers or other materials. The development of new electrodes and membranes should soon reduce the cost and maintenance









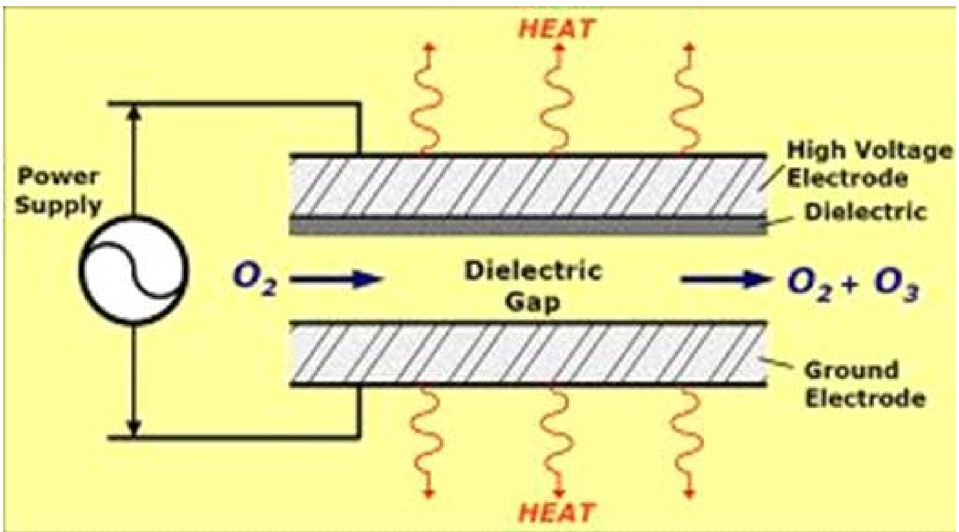
problems of these systems. Other oxidants can also be produced via This method.

Radiochemical method

High-energy irradiation of oxygen will produce ozone. This is not ueat used commercially in potable or wastewater treatment, because it is quite technical and very political. In the future this may conceivably be a good use of excess fissionable material, but currently there is much more fear of radiation that of bad water. The excess fissionable material is thus considered to be a just hazardous waster instead of a potentially valuable resource.

Photochemical method: Ultraviolet radiation

Although sunlight produces ozone in the upper atmosphere, which is not where it is needed for drinking water treatment, the photochemical principle can be applied to produce ozone where it is needed. Both black lights and UV bulbs generate wavelengths necessary to produce ozone from oxygen sources.185nm uv lamps are used to produce ozone. Air (usually ambient) is passed over an ultraviolet lamp, which splits oxygen (O_2) molecules in the gas. The resulting oxygen atoms (O_1), seeking stability, attach to other oxygen molecules, forming ozone (O_3). The output gas is injected into the water, where the ozone in the gas inactivates contaminants by actually rupturing the organisms' cell wall. Look for an ultraviolet ozone generator with a reaction chamber made from a material that provides maximum reflectivity and is engineered to isolate wiring, e lectrical connections, etc. from the effects of ultraviolet light, heat and ozone. Using ultra violet lamps ozone



concentration of about 0.1 – 0.001 % by weight can be produced.

Electrical discharge: corona discharge

Corona Discharge Generation is capable of producing high concentrations of ozone. Although there are many generation cell designs, the fundamental principal remains the same. Electrons are accelerated across an air gap, so as to give sufficient energy to split the oxygen-oxygen double bond, producing atomic oxygen. Hence this is also called as “The miniature lightening in a completely controlled and enclosed environment.”

Application of ozone in Food Industry:

- Disinfection, i.e. to kill microbes
- Deodourisation
- Decolourisation
- Taste enhancement
- Breakdown of pesticide
- Drinking water treatment
- Beverages
- Preservation and storage of produce
- Fruit and vegetable washing
- Process water recycling

Fruits and vegetable washing

Traditional technology utilizes water with or without a sanitizing agent to wash fresh fruits and vegetables. Chlorine is the most widely used sanitizing agent available for fresh produce, but it has a limited effect in killing bacteria on fruit and vegetable surfaces. The most that can be expected at permitted concentrations is a 1 – to 2-log population reduction. Furthermore, the environmental and health communities have expressed concerns about the residual by-products of chlorine.

An alternative treatment is being sought to improve food safety. Research and commercial applications have verified that ozone can replace traditional sanitizing agents and provide other benefits. Many research and industrial trials are underway to validate the use of ozone in the produce industry.

Fresh fruits and vegetables are washed first by ozonated water, and the wash water can be recaptured and treated by a combination of ozonation and filtration. The treated wash water is free of bacteria, color, and suspended solids and can be recycled to reduce water usage. Unlike conventional chlorine-based washing systems, wastewater discharged by an ozonation process is free of chemical residues, a growing concern related to the environment and groundwater pollution. Ozone can also destroy pesticides and chemical residues, such as chlorinated by-products.

Research and commercial applications have indicated that ozone can replace chlorine with more benefits. In 1997, ozone was self-affirmed as Generally Recognized As Safe (GRAS) as a disinfectant for foods by an independent panel of experts sponsored by EPRI. This self-affirmation was timely for the produce industry in light of the President’s Fruit and Vegetable Safety Initiative. The produce industry is very interested in the use of ozone and would like to know how, when, and where to apply it.

Wine industry

Sales of quality wines produced in the United States are at an all time high. Even as wine prices continue to rise, there seems to be no shortage in demand for quality products. A more knowledgeable consumer is willing to pay premium prices, but in return they demand higher quality and consistency in wines from vintage to vintage. Wine makers that can craft an outstanding, reliable product will be sure to have a loyal following ensuring financial success. Especially for high-end wineries producing limited quantities of wine, a bad vintage or a contaminated product can have a devastating impact to reputation and finances for years to come. It is no wonder that wine makers and grape growers are willing to rethink age-old techniques, investigating and using modern growing, harvesting, production and sanitation practices to guarantee a successful vintage.

Increasingly, wineries are willing to look at alternative methods to minimize contaminations from bacteria, molds, fungus, yeasts, and spores in the wine making process. Since the early 1990s wineries have been experimenting with ozone as an alternative to sanitizers like chlorines and sulfur dioxide. This has provided added benefit of reducing water usage, power consumption, and chemical treatment. Environmentally sound, ozonated cold water can replace traditional hot water and harsh chemical sanitation practices. Recently, ozone has found increasing acceptance for the barrel washing process as a sanitizer.

Even as awareness of ozone as a viable treatment alternative for wine industry increases, very few manufacturers are capable of providing expert sizing assistance, engineering, or technical support necessary to design and size a proper ozone system to fit your needs. Piper Environmental Group, Inc. has utilized ozone for food applications since 1993 and demonstrated success with both our service and application expertise. As an ozone system integrator, we evaluate your needs to design the proper ozone system for your specific wine industry application.

Ozone for Bottled Water

Municipal water companies have used ozone technology to treat large quantities of water for many years because of its effectiveness in purifying and conditioning water. Because ozone can be added at the point of water treatment and naturally reverts back to oxygen, it can keep water sanitized throughout a facility.

In the bottled water market, maintaining an optimum level of ozone at the filler is critical. If the ozone level is too high, plastic bottles may develop an aftertaste. If the level is too low, bacteria spores hidden in the water, inside the plastic walls or closure device could recover and easily contaminate the entire product.

The International Bottled Water Association (IBWA) recommends that ozone be applied in the 1.0 to 2.0 milligram per liter (mg/L) range for a period of 4 to 10 minutes contact time to safely ensure disinfection. Application at this level helps maintain a 0.1 to 0.4 ppm residual ozone level at the time of bottling. This provides an additional safety factor because the bottles can be disinfected and sanitized while filling it with product.

Water charged with ozone is also suitable for rinsing bottles and cleaning and disinfecting production equipment. This reduces the potential for bacterial growth in unchlorinated water found within the distribution system. It also reduces the amount of clean-in-place (CIP) required to keep the operation disinfected. Many plants have started incorporating an ozonated cap and bottle rinsing system.

Ozone is particularly effective when used in conjunction with other water treatment processes. By using reverse osmosis and nanofiltration or ultra filtration, organic precursors and inorganics such as bromide, can be removed from water before ozone is used. With this configuration, 99 percent of naturally occurring organic materials (such as lignin, humic and fulvic acids) can be removed, reducing the amount of ozone necessary to disinfect the water. Another benefit is that ozone will not lead to the formation of harmful trihalomethanes (THMs), which are formed when chlorine is added to raw water containing humic materials.

During the year 2000, researchers at the Department of Food Science and Technology at Ohio State University, studied the potential effectiveness of Ozonated water in decontaminating the surface of both stainless steel and laminated aseptic food packaging materials (1min). It was found that the dried film of spores could be eliminated by higher concentration of Ozone in water for both stainless steel and packaging material.

Safety Issues

Because ozone is one of the most powerful oxidizing agents known to mankind, it should be considered a hazardous material and handled as such. Hazardous as it is, it has been handled successfully and routinely in water plants for over eighty years. Food and Drug Administration (FDA) has approved the use of ozone as antimicrobial agent, which can be used as gaseous or aqueous form, in meat and poultry also.

If leaks develop in the ozonation system, the smell of ozone will become apparent. Most people can detect about 0.01 PPM in the air. This is well within the general comfort level. Symptoms experienced with concentrations at 0.1 to 1 PPM are headaches, irritation and burning of the eyes and respiratory irritation. The action level of 0.1 PPM of the ozone monitored in the ambient air for exposure to workers on a time weighted average over an eight-hour period, five days a week is the Occupational Safety and Health Administration (OSHA) maximum exposure level limit. In other words, employees can be exposed to higher levels for shorter periods of time as long as they do not exceed the average exposure of 0.1 PPM over eight hours.

To provide for accidental discharges of ozone it is recommended to install an ambient air ozone monitor at an appropriate point or points within the equipment room. These monitors are set to signal at a minimum 0.1 PPM. Additionally, these monitors can be connected to exhaust fans that trip when the alarm is activated and/or cutoff the electrical supply to the ozone generator. There are also personal ozone exposure level badges that employees can wear individually. Ambient ozone will dissipate rapidly. Ozone is not characterized as a carcinogen or mutagen. It does not accumulate in fatty tissue or cause long term chronic effects. Even though throat and lung irritation plus oedema have been observed after extreme exposures to ozone, it is important to recognize that during more than 100 years of commercial use, no deaths related to ozone exposure have ever been reported.

CONCLUSION

Currently, there are many State Universities now doing research on Ozone while others are planning to do research. New uses are being discovered every day and will be a big part in every one's life in the very near future. If ozone would cease to exist, life on this planet would also cease to exist. Ozone is nature's way of purifying the air we breathe. The use of Ozone on the foods we consume will be the only "natural alternative" to chemicals or gamma radiation to control pathogens and to increase shelf life

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