Ozone Treatment

Definition: Ozone (O_3) is a naturally occurring, pale blue gas that makes up the familiar UV- shielding "ozone layer" in the Earth's stratosphere. Unlike oxygen molecules (O_2), ozone molecules are composed of 3 oxygen atoms (O_3) instead of the two. Ozone is an unstable gas that readily decomposes into oxygen and it has a half-life of only 20 minutes in room temperature water. Ozone is formed naturally through the electrical discharge produced by lightning or when the sun's ultra-violet rays reacts with the Earth's stratosphere.

Ozone can also be produced commercially with the help of ozone generators. Ozone generators produce ozone by creating an electrical discharge across a flow of either pure oxygen or air. Since ozone is highly reactive, and has a short half-life, it cannot be stored as a gas or transported, consequently ozone is always generated on site for immediate use.

Uses in Canada's Food Industry

Ozone is a strong oxidizing and sanitizing agent capable of killing numerous microorganisms by oxidizing their cell membranes. Scientific evidence suggests that ozone is more effective than chlorine at eliminating a wider variety of potential pathogens including bacteria, parasites, and mould and yeast spores. Unlike many other sanitizing agents, ozone does not negatively impact the environment because it quickly and easily degrades into oxygen (O_2). In Canada, ozone is used in several industrial applications including:

Water Treatment: In Canada, relatively few water treatment plants (except in Quebec) use ozone for disinfection. Typically, disinfection by ozone, chlorine or ultraviolet radiation constitutes the final step in municipal water treatment. When ozone is applied, as a gas, for drinking water treatment, it is done primarily because of its oxidative strength. This powerful oxidation potential allows ozone to effectively reduce or eliminate off color, aftertaste and odor, all of which may be fundamental problems associated with a specific water supply. More importantly, ozone will effectively destroy bacteria and inactivate viruses more rapidly than any other disinfectant chemical. Ozone will also oxidize heavy metals. Iron and manganese can be reduced to very low, safe levels in water supplies through ozone oxidation.

In the bottling industry, ozone is often added to the water as soon as the water is collected. Its level in the water is kept constant throughout the bottling process to inhibit the growth of microorganisms.

Food Industry: Ozone can be bubbled through water into which it will partially dissolve. This ozonated water then can be used for washing foods, particularly produce and poultry, to reduce microbial loads. Controlled studies report that ozonated water may actually provide greater than 90% reduction of total bacterial

counts for some vegetables. Such treatments have also been shown to reduce fungal decay. Besides reducing microbial loads in wash water, ozone can extend the shelf life of produce in storage. However, this application is not permitted in Canada (see Canadian Regulations). For storage applications, the ozone is emitted periodically into the storage area. As with many oxidizing agents, exposure to high enough concentrations of ozone is harmful to humans. Ozonated storage areas should be enclosed and the ozone allowed to dissipate prior to workers entering the area.

During the ozonation process, ozone is readily consumed. Thus, wash water must be ozonated continually. Typically poultry and produce processing use a great deal of water. Thus, ozone can be used for treating recirculated water in poultry and produce processing industries. Ozonating this water allows it to be reused, thus providing cost savings.

Ozone is also permitted for use in Canada as a food additive at a maximum level of use consistent with good manufacturing practice. Ozone is used as a maturing agent (speeds up the aging process) in cider and wine and as a chemosterilant (controls pest populations) in water represented as mineral or spring water.

Canadian Regulations

As stated above, ozone is permitted for use in Canada as a food additive at a maximum level used consistent with good manufacturing practice. Ozone is currently used in cider and wine to speed up the aging process and in mineral and spring water to reduce microbial populations. Health Canada has also approved the use of ozone for the sanitation of food contact surfaces.

The application of ozone to the water supply including recirculated wash water is permitted as an acceptable water treatment provided that the following conditions are met:

1. The amount of ozone added to the water does not exceed the minimum level required to effectively reduce the microbial levels in the water (including water to make ice) in accordance with Good Manufacturing Practices (GMPs). A processor and the manufacturer of the ozone generating equipment should determine and validate the amount of ozone needed to achieve disinfection and no more than that amount would be added.
2. The concentration of residual (remaining) ozone in the water that may come into direct contact with the fresh food is negligible. In other words, Good Manufacturing Practices would be applied and no more ozone other than that which is needed for disinfection would be applied to the water resulting in minimal or no residual ozone.

3. If present, residual (remaining) ozone in recirculated wash water would not bring about a change in the characteristics of the fresh food and shall be removed (e.g. filtered) from the wash water prior to its contact with produce or poultry carcasses/parts.
4. The ozone in the system is not used for the purpose of preservation of the fresh food.
5. The ozone generator shall not generate ozone into the air, incidental to their normal operation, at a level in excess of 0.05 ppm.

Labeling Regulations: The current regulations for bottled water require that producers who add ozone to mineral water or spring water must include a statement to this effect on the principal display panel of the product label. But rules governing food additives also require that the added ozone be listed as an ingredient. So under the current Regulations, ozone, when added to spring water or mineral water, must be listed on the product label twice: in the products list of ingredients and in a separate statement on the principal display panel.

Efficiency of Ozone

To date, the most commonly used drinking water disinfectants in Canada include chlorine, chloramine, UV light, ozone, and chlorine dioxide. Compared to chlorine-based disinfectants, ozone is more efficient in the inactivation of bacteria, viruses, and protozoa. Similar to UV light, ozone is highly effective at the point of treatment, but an additional disinfectant (usually chlorine or chloramine) needs to be added to supply a residual effect.

The efficacy of disinfection can be predicted based on a knowledge of the residual concentration of disinfectant, temperature, pH (for chlorine and chloramine), and contact time. This relationship is commonly referred to as the CT concept and is used by public supply systems as one tool for ensuring adequate inactivation of organisms during disinfection. The table below provides CT values for 99% inactivation of selected bacteria using different disinfectants at 5°C. CT values are the product of C (the residual concentration of disinfectant, measured in mg/L) and T (the disinfectant contact time, measured in minutes).

Table: CT values for 99% inactivation at 5°C

Disinfectant agent	pH	*E. coli*[a] (mg•min/L)	*Giardia lamblia*[b] (mg•min/L)	Poliovirus 1[a] (mg•min/L)
Free chlorine	6–7	0.034–0.05	32–46[c]	1.1–2.5
Preformed chloramines	8–9	95–180	1470	768–3740
Chlorine dioxide	6–7	0.4–0.75	17	0.2–6.7
Ozone	**6–7**	**0.02**	**1.3**	**0.1–0.2**

Source: Health Canada (2008).

From this table, it is apparent that, coliform bacteria (bacteria naturally present in the intestines of humans and animals) are easier to inactivate using common chemical disinfectants compared to most protozoans and viruses. It is also apparent that chloramines have a much higher CT value than any of the other disinfectants listed. This means that in order to achieve the same level of inactivation with chloramine, a higher disinfectant concentration or a longer contact time, or a combination of both, is necessary. Conversely, ozone has the lowest CT values than the other disinfectants listed which means that a lower concentration or shorter contact time is necessary to achieve the same level of inactivation as the other disinfectants.

Controlled studies also report that ozonated water may actually provide greater than 90% reduction of total bacterial counts for some produce. A study conducted by Hongde Zhou at the University of Guelph found that ozone is able to effectively inactivate all test microorganisms (*E.coli O157:H7, Listeria spp*, and *Salmonella*) present on the surface of fresh vegetables and fruits (OMAFRA, 2002). This researcher found that ozone treatment at a dose of less than 10 mg/L was as effective in destroying all test microorganisms present on the produce samples as chlorine at a dose of 200 mg/L. The inactivation efficiencies increased as the ozone dose increased. However, the inactivation would be leveled off after the contact time became more than 5-minutes, perhaps due to the presence of more resistant microorganisms. In addition, ozone treatment had little negative effects on food quality (produces no taste or odour in the water) and was very effective in eliminating the microorganisms present in water, thereby, providing a great potential to reuse the food processing water in practice.

Ozone generators are costly, complicated, and require a high level of technical competence to operate and maintain. Unlike chlorine and iodine, ozone does not protect the water after application and is often combined with activated carbon filtration to achieve a more complete water treatment.

Health Concerns

Health Canada conducted a study which showed that both high and low concentrations of ozone can be detrimental to human health. High levels of ozone resulted in immediate oxidizing effects and cellular death, while low levels of ozone resulted in an interference with metabolic processes in the body and eventually caused premature cellular aging. Ozone gas is also an irritant that can cause coughs, chest discomfort, and irritation of the nose, throat, and trachea.

Also, as a powerful oxidizing agent, ozone can transform bromide--a naturally occurring element in water--into bromate, a carcinogen (cancer causing agent). The concentration of bromide in raw water is a major factor in the formation of bromate. The major natural sources of bromide in groundwater are saltwater intrusion and

bromide dissolution from sedimentary rocks. Sewage and industrial effluent as well as road and agricultural runoff may also contribute to elevated bromide levels in surface waters. For most Canadians, exposure to bromate is unlikely to be significant, because relatively few Canadian treatment plants (except in Quebec) use ozone for disinfection. This situation may change as water utilities seek alternatives to chlorination. An interim standard (IMAC) has recently been developed for bromate in the *Guidelines for Canadian Drinking Water Quality*.

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For more information on Ozone Treatment or other Food Safety topics, please call the Food Safety Network toll-free at 1-866-50-FSNET (37638) or visit www.foodsafetynetwork.ca