Ozonation in soilless cultures. Part I: techniques

Elly Nederhoff
CropHouse Ltd, New Zealand
Elly@CropHouse.co.nz
Published in the Commercial Grower 55(11), 2000, p. 50-52

This series of articles is about controlling pathogens (disease-causing organisms) in water. This may apply to raw water (used for making the nutrient solution), recirculating drain water (run-off) from soilless cultures as well as to water to wash vegetables. Previous articles dealt with heat-treatment, UV-radiation and hydrogen peroxide. The present article is about ozone, in particular the techniques of ozonation.

Ozone
Ozone (O_3) is a natural gas, consisting of oxygen (O_2) and one extra oxygen atom (O). In nature, ozone is formed when oxygen is exposed to electricity from lightning or exposed to UV from the sun. It can also be produced artificially. Ozone is an oxidant like chlorine, bromine and hydrogen peroxide, with ozone being the most powerful commercially available oxidant. On contact with any substance, ozone quickly oxidises ('burns') the other substance. Both the ozone and the other substance disappear in this process. Only some materials are not affected such as glass, stainless steel, silicone, viton (Mebalds et al., 1998). Ozone does not leave a chemical residue, as for instance chlorine does.
Ozone is very unstable. The rate of decomposing is only minutes for ozone dissolved in dirty water, some hours for ozone dissolved in distilled water, and a few days for ozone gas in a clean glass laboratory bottle (Diatloff, 1994). Therefore ozone cannot be stored and it has to be produced on the spot.
Ozone has been used for over 100 years for drinking water treatment. It is now widely used for municipal and wastewater, beverage and food industry, swimming pools as well as in horticulture.

Safety
Ozone is a dangerous gas. The safety limit for an eight-hour exposure period is as low as 0.1 ppm. Fortunately, humans can smell very low concentrations of ozone in air (around 0.01 ppm or even 0.001 ppm), while 0.1 ppm gives a notable acrid smell. Also plants are sensitive for ozone: water in contact with plants should not contain more than 0.1 ppm ozone at peaks only (Evans & Vestergard, 1997).
Because ozone is so unstable, it must be produced on the place where it is needed. This means that ozone is not stored in bulk, unlike other oxidants such as chlorine or hydrogen peroxide. Thus ozone does not cause any risks associated with storage of hazardous substances.
In the past there were only relatively large ozone installations available. When these were used in a small greenhouse operation it was easy to overdose, causing potential hazards for humans and/or plants. Nowadays the grower can choose a small ozone installation that fits the water volume to be treated, so that the risk of overdosing is minimal.

The technique of ozonation
The ozonation process requires a few steps:
1. Filtering the water or nutrient solution to reduce the organic load
2. Air preparation or oxygen production
3. Ozone generation
4. Ozone diffusion to introduce ozone gas into water
5. Ozone off-gas destruction

<u>Filtration</u>. All organic compounds in water react with ozone and directly reduce the amount of ozone available for pathogen control. Therefore the organic contamination has to be filtered out prior to ozonation.

Air preparation. Ozone is produced from oxygen. Oxygen can be produced by an oxygen generator on site. However, the smaller systems just use air (containing 21% oxygen) as the feed gas. It is important that the air is filtered and dried.

Ozone generation

There are two methods of generating ozone. The ultra-violet (UV) irradiation method is the least efficient method. Air is passed across a UV light and a small amount of ozone is formed which is then introduced into water. UV-ozone systems are small systems with a small production capacity, for instance 0.1 gram ozone per hour and upwards to a few gram/hour. Typically this results in 0.01 – 0.1 % ozone (by weight) in the gas stream. An advantage of this system is that it can use normal air as feed gas and there is no need to filter and dry the air.

The other method is the Corona Discharge method (CD or CDG), which is often applied in horticultural installations. Oxygen or dry air is passed between two electrodes with a high voltage (>10 kiloVolt), separated by a dielectric material (e.g. ceramic) and an air gap. The process that occurs in the gap produces ozone, heat and light ('corona' means crown of light). The generator has to be cooled, which in smaller systems is done by air and in larger systems by the water that is being treated. The efficiency of a CDG depends on many variables, including the type of feed gas (air or oxygen) and the cooling efficiency. The capacity of CDG ranges from around 0.1 gram ozone per hour to in the order of 100 gram per hour (and more). The ozone concentration in the gas stream ranges from 0.5 - 2.0 % (by weight) when dried air is the feed gas, or over 6 % when oxygen is the feed gas.

Introduction of ozone into water

After the ozone is produced it has to be mixed with the water. It is not easy to dissolve ozone (a gas) in water. Important factors are the concentration of ozone in the gas stream, the water temperature and the contact time between gas and water. As an example, in one good system 80% of the ozone produced is successfully transferred into the water, and the remaining 20% escape as 'off-gas'.

For horticulture, two methods are used for introducing ozone in water: (1) pushing the ozone into the water via fine bubble diffusers and (2) pulling ozone into the water via a venturi system.

In the first method, a series of fine-bubble diffusers/contactors discharge the ozone gas from the generator directly into the nutrient solution at a small overpressure. A high efficiency (>90%) can be achieved with multipoint injection, deep contact chambers (not practical for small systems!) and recycling the off-gas. Diffusers may give clogging problems.

In the second method, a stream of water ('recirculating stream') is led through an orifice, creating a venturi effect that pulls the gas from the ozonator into the water stream. The ozonated stream is then injected into the main water flow. The ozone production stops as soon as the water flow stops, so that there is no risk of ozone escaping. This system requires a contact tank (degassing tank or reaction tank) to achieve the necessary contact of ozone with the batch of water to be treated. This tank is smaller than the deep contact chambers required for bubble diffusion. This method of introducing ozone in water is used for smaller and medium size applications. It requires additional energy to run the 'recirculation pump' that creates the venturi flow.

Off-gas destruction

Undissolved ozone gas escaping from the generator (off-gas) is dangerous when it comes into the working environment. On most horticultural properties, however, the ozone installation is outside, or the off-gases can easily be vented to outside. Very small systems are not a health hazard. Slightly bigger systems can be equipped with an activated carbon filter which converts off-gas ozone into oxygen. Larger ozone systems either use the off-gas for pre-ozonation, or destruct it catalytically. Other off-gas destruction methods are UV-C radiation, or heating to above 350 ^{o}C. Proper off-gas destruction is required for systems that use oxygen as the feed gas or that produce high ozone concentrations or large amounts of ozone off-gas.

Residue

If there is any residual ozone in the nutrient solution, it can damage the roots. However, usually the ozone levels are low and the ozone decomposes very rapidly. If not, the retention time must be increased: the water is left in the tank for an extra half an hour, or is put through a sand filter.

Advantages

Ozone has some advantages over other methods, for example:

- environmentally safe (leaves no residue)
- strongest oxidising (sterilising) agent available
- fast sterilisation action
- removes organic compounds and pesticides
- flocculates soluble iron and manganese in (bore) water
- adds oxygen to the water

The most important question, however, is if ozone is effective against pathogens. Unfortunately not much research has been done on the use of ozone for pathogen control. The knowledge about effects is more anecdotal than scientific. The efficacy of ozone as well as the required concentration, contact time etc. will be discussed in the next issue.

***Acknowledgements**. With special thanks to Mr. Neil MacDonald of **Novozone**, Auckland and Mr. Steve Warne of **Contamination Control Ltd**, Auckland for providing information and reviewing this article.*

Literature references:

Evans & Vestergard, 1997. Recirculating water treatment technologies for closed-cycle plant growth systems. Proc. 18th ann. conf. of Hydroponic Society of America (in Windsor), page 75-86.

Mebalds et al., 1998. Disinfection of water for hydroponic systems. Practical Hydroponics & Greenhouses, March/April, page 74-78.

Diatloff, 1994. Ozone sterilisation. Practical Hydroponics & Greenhouses, September/October, page 31-34.

