Ozonation in soilless cultures. Part II: dose and contact time

Elly Nederhoff
CropHouse Ltd, New Zealand
Elly@CropHouse.co.nz
Published in the Grower 56(1), 2001, p. 41-43

The previous article in this series dealt with the techniques of ozonation. This time we discuss the use of ozone to control plant pathogens (disease-causing organisms) in nutrient solutions. Unfortunately not much research has been done in this field, certainly not in recent years. We report on what is known about the required concentration, contact time and recommended dose. In the next article we hope to describe experiences with ozone from NZ growers.

Popularity of ozone

Ozone is a powerful oxidant that effectively destroys organic material by oxidation ('burning'). It is used for drinking water, food industry, swimming pool water treatment plus many other applications. In horticulture, it is used for various purposes. Ozonation is an effective method for removing iron, manganese, sulphur, organic matter, bacteria etc. from raw water (source water). It also can kill pathogens such as bacteria, fungal spores and viruses in raw water or in nutrient solution. It breaks down algae, herbicides and pesticides. Ozone leaves no unpleasant residue. The only by-product is oxygen. A positive side effect of ozonation is that the plant roots get more oxygen.

However, ozone is not as popular as some other methods for the disinfection of nutrient solutions. At least this is the case in several countries including in the Netherlands (Holland), which is still leading technical development in commercial soilless cultures. In Holland, the most popular method is disinfection by heating, because all growers get natural gas for a reasonable price. Slow sand filtration is (or was) popular due to a governmental subsidy. UV systems proved successful and were more convenient than the ozone systems available at that time. Also, ozonation has the disadvantage of difficulties with measuring ozone. This may explain - but not justify- its lesser popularity.

Ozone contact vessel

The ozone concentration that destroys pathogens can also damage the roots. Therefore ozone is not applied directly in the soilless system, but always in a separate contact vessel that holds a certain volume of water or nutrient solution. The ozone action takes place in the vessel, and at the same time the ozone quickly declines. After a certain time in the vessel, the water is disinfected and virtually free of ozone. The ozone must have disappeared by the time the water reaches the roots. There is hardly any risk of overdosing if the ozone generator is of the right capacity.

Of course only the water (or nutrient solution) inside the vessel is disinfected, and there is no control of pathogens residing on the roots, in the gullies or elsewhere in the system. The good thing about this is that the beneficial micro-organisms living on the roots are not affected by ozone either.

Measures and units

Various measures and units are used in relation to ozonation.

Ozone generators are characterised by the production capacity in gram per hour. A very small generator produces 0.1 g/h, while the bigger units used in horticulture produce 10 g/h, and huge systems produce over 100 g/h (see previous article about various types of generators).

The ozone supply to water is expressed as gram ozone per hour per m^3 water. For instance the supply can be 10 $g/m^3/h$. Gram per m^3 (g/m^3) equals part per million (ppm). So we can say the supply is 10 ppm/h. However, an ozone supply of 10 $g/m^3/h$ does not result in ozone concentration of 10 ppm, because the residual concentration depends on supply rate, absorption rate and breakdown rate (which in turn depends on the organic load of the water).
The residual concentration of ozone in water is expressed in ppm = mg/litre = g/m^3. A concentration of 0.1 ppm is low (but already strong enough to cause some root damage) and 5 ppm is very high.

An ozone treatment needs a certain contact time (CT value) to be effective. The strength of an ozone treatment is expressed as CT value, which is the combination of concentration (C in ppm = mg/l = g/m^3) and contact time (T in minutes). CT is given as ppm x minutes.

ORP is another indication of the ozone concentration. ORP = Oxidation Reduction Potential = redox potential = redox value. It is expressed in mV. In theory the maximum ORP value is reached at maximum ozone concentration (which depends on the temperature). This may work very well in clean water, but in recirculating nutrient solutions, the ORP measurement is inaccurate. Researchers have not been able to determine a clear relationship between redox potential and the residual ozone concentration in nutrient solutions, especially not beyond 1 ppm. The use of ORP measurements is not recommended in nutrient solution (Mebalds et al., 1998, Runia 1990).

Recommended concentration
Australian researchers determined that a high level of 1.5 ppm can kill Pythium, Phytophthora and Fusarium in 4-8 minutes (Mebalds et al., 1998). However, most ozone installations in soilless cultures achieve only low levels (such as 0.1 ppm), and a much longer contact time is needed to achieve the same control. The user of ozone wants guidelines about the required concentration and contact time. However, it is hard to measure the concentration of ozone in a nutrient solution (see above), and thus guidelines about required ozone concentration are not so useful and can hardly be found.

Recommended dose
Instead of guidelines for concentration and contact time, the other option is to use the dosing rate, or actually the ozone production rate. Also this approach has some difficulties. Firstly, not all ozone produced by the generator is transferred into the water. Secondly, ozone breaks down quickly and the rate of decline depends on the presence of dirt, iron, etc. Hence there is no relationship between dosing rate and residual concentration. Nevertheless, the dosing rate is often used as a guideline. It is based on experimental work done in the Netherlands in the early nineties (Runia, 1994). The guidelines in Holland (DLV, 1995) for disinfection of nutrient solutions are as follows.

- Use a contact vessel of for instance 2 m^3, with the nutrient solution flowing along an ozone injector for an hour.
- The pH is lowered to about 4 to increase the efficacy of ozone (but this is not always found in other guidelines).
- The required dose depends on the cleanness of the water and on the type of pathogen, as follows:
    - A dosing rate of 5 gram ozone per m^3 water per hour is sufficient to treat clean raw water.
    - At least 10 $g/m^3/h$ is needed to treat recycled nutrient solution possibly containing fungal spores.
    - At least double this amount is needed if viruses or nematodes need to be controlled.
    - The survival structures of Verticillium were even harder to control (Runia, 1995).

Of course in smaller soilless systems with smaller water volumes, the volume of the contact vessel and the dose rate are reduced accordingly.

Summary

Ozonation is a very powerful water treatment method. It is very effective for removal of iron, bacteria etc. from raw water (source water). But disinfection of nutrient solutions is more complicated. In theory, a certain residual concentration and contact time are required to kill a certain pathogen. But in practice the residual ozone concentration cannot be measured accurately in a nutrient solution.

Therefore the practical guidelines are based on dosing rate, but these guidelines are vague. At least a dosing rate of 5-10 gram ozone is required per m^3 water per hour during an hour; and double this dose (or more) is needed for dirtier water and for tougher diseases. The ozone must have disappeared before the nutrient solution comes in contact with the plants.

Literature references

DLV, 1995. Ontsmetten van drainwater (Disinfection of drain water). DLV, Naaldwijk, The Netherlands.

Mebalds, Bankier & Beardsell, 1998, Disinfection of water for hydroponic systems. Part 1: ozone. Practical Hydroponics & Greenhouses, Jan/Feb. 1998, p.56-59.

Runia 1994, Disinfection of recirculation water from closed cultivation systems with ozone. Acta Horticulturae 612, p. 221-229.

***Acknowledgements**. With special thanks to Mr. Neil MacDonald of Novozone, Auckland for some information.*