Sterilisation: heat treatment for pathogen control in water for soilless cultures

Elly Nederhoff
CropHouse Ltd, New Zealand
Elly@CropHouse.co.nz
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Sterilisation or heat treatment is a powerful method of controlling pathogens in water or in re-usable nutrient solution for soilless cultures. Adequate heating kills 'everything' including fungi, viruses, bacteria and nematodes. The disadvantage of this method is the high energy demand. Hence pasteurisation is feasible only when natural gas is available. The flue gases from natural gas combustion can be utilised for CO2 enrichment. Sterilisation is the number one water treatment method in the Netherlands and it is common in many other countries where natural gas is available at a reasonable price. In New Zealand the method is still new, but some of the major growers are looking into this interesting option.

Principle
Louis Pasteur discovered in 1866 that bacteria in milk are killed by heating. Nowadays we distinguish pasteurisation (heating to 70 °C) and sterilisation (heating to 100 °C). In soilless cultures, sterilisation was used for the first time on a commercial scale in The Netherlands in 1987. Since then, heat treatment has been in use on a large scale in vegetable crops and ornamentals. Pasteurisation is safe, low-risk, easy to handle and to comprehend. It only requires a coarse pre-filtration but no additional water treatment is needed. It has no residual effect, that is, nothing happens after the treatment. For instance it does not affect organisms in the irrigation line, drippers or on the roots. It is considered an advantage that the micro life on the roots is not disturbed (but no pathogens on the roots are killed either). It is also a disadvantage that it does not clean any blocked lines. Sterilisation does not affect the composition of the nutrient solution, apart from possible loss of calcium (see below). The installation must be built of corrosion-free materials (e.g. stainless steel or synthetics) and of course must be heat-proof. Materials containing copper and zinc cannot be used as they are toxic for plants.

Required temperature and energy
The standard method of heat treatment for a decade was to heat the water (or nutrient solution) to 95 °C for 30 seconds. But new research in the Netherlands (Runia, 1998) demonstrated that a lower peak temperature (85-90 °C) is sufficient provided the exposure time is longer. It was found that the normal method (95 °C for 30 seconds) could be replaced by 90 °C for 2 minutes, or 87 °C for 2 minutes and 30 seconds, or 85 °C for 3 minutes. These treatments all give the same perfect control. Hence many systems are now applying the lower temperature and longer exposure time (see further).
Heating water costs a lot of energy. But the water treatment systems are set up with heat exchangers so that the energy is largely re-used. This reduces the energy requirement considerably, but it is still high. The net amount of energy needed to disinfect 1 m^3 of water is 0.8 - 1 m^3 of Dutch natural gas, which is about 28-35 MJ or nearly 8-10 kWh. At the moment the gas price in The Netherlands is around NZ$0.25 per m^3 natural gas. Hence the costs of sterilisation are around NZ$ 0.20-0.25 per m^3 water, which makes sterilisation by far the cheapest method for water treatment over there. The New Zealand natural gas contains a bit more energy than the Dutch gas, and so here sterilisation would require slightly less than 0.8-1 m^3 gas per m^3 water. Natural gas is available in larger parts of the North Island. The Natural Gas Corporation is happy to talk to anybody interested in the possibilities of using natural gas.

Scaling

Source water may contain calcium, bicarbonate and other compounds and it may have a high pH. Nutrient solution contains large amounts of calcium from the fertiliser. Heating will cause calcium to precipitate and form scale on the heat exchangers. Scaling is not so bad at 70 °C but worse at 90 °C and very severe at 100 °C. Scaling can be avoided to a great extent by lowering the pH of the water or nutrient solution before it enters the steriliser. For sterilising water, the pH is lowered somewhat, depending on the quality of the water. For sterilising re-usable nutrient solution, nitric acid is added to a pH of about 4. This nitric acid is later compensated when the treated nutrient solution is mixed with an overdose of fresh water with a higher pH. Nitric acid is also used (a solution with a pH of about 2) to clean the steriliser when it is blocked.

Sterilisation process

The water or run-off to be treated is collected in a tank, filtered by a simple filter (about 300 micron is sufficient) and then pumped into the sterilising system. Nitric acid is added to reduce scaling. In most systems the water is heated in two steps by two heat exchangers (see figure). In the first heat exchanger, the incoming water is pre-heated to about 80 °C by absorbing the heat from water that has already undergone the heat treatment. The next step is that the incoming water is heated further to the required peak temperature (e.g. 95 °C), usually also in a heat exchanger (number 2). Here the external energy (from a boiler) is brought into the system. The water then flows through a long line where the peak temperature is maintained for a certain period of time (30 seconds to 3 minutes depending on the temperature). Here the actual disinfecting takes place. Directly after this disinfection, the water flows through the first heat exchanger again, but this time through the hot side, to give its heat to the incoming water. In this step the treated water is cooled down to an acceptable temperature (e.g. 30 °C). The process is fast: 2 s for heating up, 30-180 s for the treatment, and also 2 s for cooling down. There are several types of specialised water sterilisation systems available from various (Dutch) manufacturers.

Using the main boiler

The new findings that lower peak temperatures are sufficient (with a longer exposure time), opened the possibility to use the normal heating boiler for water disinfection. This means that the main boiler can be used to provide the hot water to heat exchanger number 2, which saves the purchase of a special burner. Another advantage is that the flue gases can be used more easily for CO_2 enrichment. A gas-fired boiler produces clean combustion gases (if it is set-up properly), and can be readily connected to a CO_2-unit (which is basically a fan and CO_2 distribution network). If the central boiler is already used for CO_2 enrichment (also when heating is not needed), then the combustion gases from the heat treatment can go straight into this CO_2 unit. Although the water sterilisation process produces only a fraction of the CO_2 that the plants would like to receive, at least the combustion gases are not wasted. Both the water treatment and CO_2 enrichment have their peak demand during warm sunny weather.

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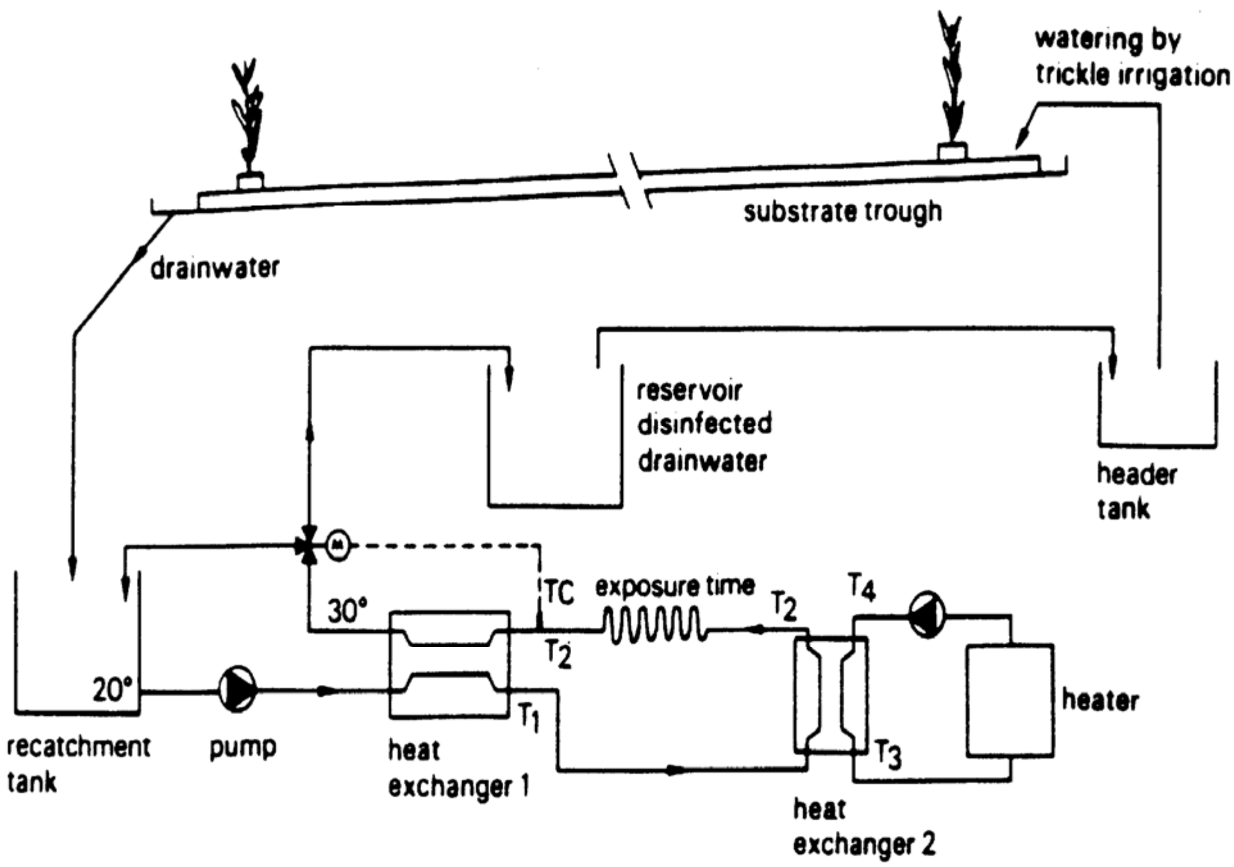

Scheme of a sterilisation system (from Van Os, 1988). E.g. T_1 = 75 °C; T_2 = 95 °C;
TC = temperature check: if water is not at required temperature, it is sterilised again.