UV Disinfection of Water in Horticultural Applications

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ABSTRACT

Safe recirculation of horticultural water requires disinfection for plant pathogens. UV-C light is suitable, but specific aspects have to be considered: low and varying UV transmittance, different cultures and pathogens. Proper disinfection conditions for a log 3 reduction have been established for several pathogens. Equipment developed has been designed such that intensity of UV-C and residence time are varied automatically for optimal capacity and energy use, depending on water quality and required dose. Automatic cleaning is possible during the disinfection process.

Investigations with UV oxidation show that lower doses UV are possible by adding hydrogen peroxide (H_2O_2) just before the UV disinfection. Also substantial lower levels of residual pesticides are achievable.

Key Words: UV, Disinfection, Horticulture, UV/H_2O_2

INTRODUCTION

Horticulture in the Netherlands is characterized by strongly intensified cultures which are grown in greenhouses. Many crops are cultivated without soil and use inorganic or organic substrates as growing media. Illumination is used widely for assimilation, especially in the dark season. Automation for climate, irrigation and fertigation has been implemented widely.

High use of water and fertilisers is required and both are becoming scarce and more expensive. Rain water collection is applied widely as surface water varies in quality and well water is brackish in many cases. But rain water is not sufficient in dry periods.

Water disposal is becoming more expensive and is ecologically not acceptable. Disposal of brine from reverse osmosis will be forbidden in some areas within a few years.

In horticulture world wide the same trends apply: cultures are intensifying, irrigation is more controlled an environmental legislation becoming stricter, see for example EU directive 2000/60/EU. In many areas there is scarcity of suitable water (arid regions, dry seasons). The quality of the water may vary, especially for (unwanted) sodium and chloride content. Other contaminants may also be present. Also pH can be too high by elevated level of bicarbonate.

Loss of water can be limited most easily by reuse of the water returned from the culture. But this drain water may contain plant pathogens like fungi, bacteria, viruses or nematodes. UV disinfection can eliminate these pathogens in an effective and economic way.

Disinfection with MP-UV

Disinfection by MP-UV is a known method for years, widely used worldwide for drinking water[1]. The disinfection effect has been determined scientifically. UV disinfection is time, space & energy effective, as a short residence time in a relatively small unit is sufficient. Alternative methods like heating or ozone give an often undesired effect of temperature rise or residual chemicals. UV systems are closed and safe for operators.

Drain water from horticulture has some specific aspects compared to clean water like tap water. Typically transmittance T10 (% UV transmitted through 10mm) is low and around 20-30% at 254nm. Also T10 may change by the UV treatment. See **Figure 1**.

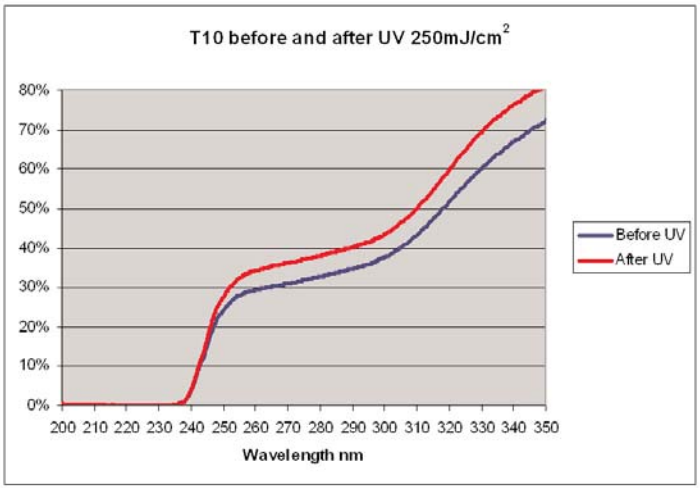

Figure 1: Example of typical transmittance curve for horticultural water

Low transmittance is caused by some fertilizers which absorb UV (mainly iron and below 250nm nitrate). Some organic growing media leach UV absorbing materials (especially when fresh). Also biotic matter from the root environment may absorb UV. As a consequence T10 varies during different stages of the culture.

Drain water may contain a lot of dirt and jelly like particles, much more than clean water – but less than sewer water. These particles have to be removed by proper filtration. Some fertilisers may cause contamination on the quartz tube surface. Usually main components of these deposits are calcium phosphates and thus the solubility of these deposits is pH dependent: they can dissolve again at lower pH.

Germicidal Effectiveness of UV-C and Determination of Required Doses

The determinations of required disinfection doses have been made with "Applied Plant Research Institute", Naaldwijk (NL), which is an independent institute, now part of Wageningen University.

Presumptions used are:

- Test in actual drain water from horticulture
- Test at different and actual UV transmittance (T10) levels (around 20%)
- Log 3 reduction target – minimum 99,9% of pathogens eliminated
- Lamp at end of life cycle (25% less power)
- Take into account only germicidal effective part of UV-C light
- Minimum intensity of 5mW/cm^2 everywhere in disinfection chamber
- Turbulent flow in chamber (Reynolds number > 4000)
- Pre sand filtration for removal of particles (0.4 mm sand fraction, <= 10 m / hour water speed): maximum particle size 25µm and dirt load (suspended solids) maximum 5mg/l

In the different tests following doses UV light required for disinfection have been determined:

1. 1991 Fungi 100mJ/cm^2, virus (TMV) 250 mJ/cm^2
2. 1996 Nematodes: no reproduction after exposure to 20mJ/cm^2, population thus eliminated
3. 1998 T10 low limits for guaranteed log 3 reduction: 10% (fungi) 15% (virus). At T10 between 10 and 20%: required dose needs a correction for guaranteed log 3 reduction
4. 1999 – Pepino mosaic vírus dose 150 mJ/cm^2
5. 2002 – Investigation on modernised equipment: Fusarium 80 mJ/cm^2 , Pythium / Phythophthora 60 mJ/cm^2, TMV virus confirmed 250mJ/cm^2.

Minimum UV exposure time applied is 1 second (when virus pathogens have to be inactivated) or 0.7 sec (for bacteria-fungi-nematodes). Accurate dose measurement and control is ensured by continuous monitoring of UV-C intensity and water flow.

It has been proven, that a combination of UV and H_2O_2 (advanced oxidation) permits lower dose of UV light for same reduction level of pathogens. The effect is dependent on pathogen, pH (lower pH better). The tests in horticultural water with Vialux MP-UV have given following results:

1. TMV virus 250mJ/cm^2 → 170mJ/cm^2; at pH 4: 100mJ/cm^2 is sufficient
2. Fusarium 80mJ/cm^2 → 60 mJ/cm^2
3. Pythium 60mJ/cm^2 → 20mJ/cm^2

Recent investigations with Vialux MP-UV in horticultural drain water have shown that H_2O_2 reduces residue levels of many pesticides significantly more strongly than the separate treatments with UV and H_2O_2. The effect on plant growth of combination of UV and H_2O_2 is being investigated and first indications are very positive.

Vialux Disinfection Units

Vialux disinfectors are built around a cylindrical disinfection chamber. Two chamber sizes are in use with a water layer thickness of around 18mm (suitable for T10 $\geq$ 10%) or 31mm (T10 $\geq$ 27%) to enable proper and economic disinfection of horticultural water. The MP UV lamp has a power of 6, 9 or 12kW. This power is scalable to lower levels for energy efficiency. Flow is used also to optimize capacity at the required dose. A capacity of 2-39m^3/hr is thus possible.

Energy consumption of lamp for disinfection varies around 0.4 – 2 kWh/m^3, and is strongly dependent on required dose of UV-C, T10, chamber and lamp power.

Cleaning is made by Nitric Acid dosing, assisted by a wiper. This is done at start up, to ensure a clean quartz tube before the determination of the actual T10 transmittance, but also during production cleaning is possible. UV dose is calculated continuously based on actual flow and UV-C intensity determinations.

A Vialux project definition starts with measurement of actual T10 range, the potential disease(s) which may spread through the water in the actual cultures grown and the required capacity in the top season.

Capacity curves and a calculation module are available. Example curves are shown in **Figures 2 and 3**:

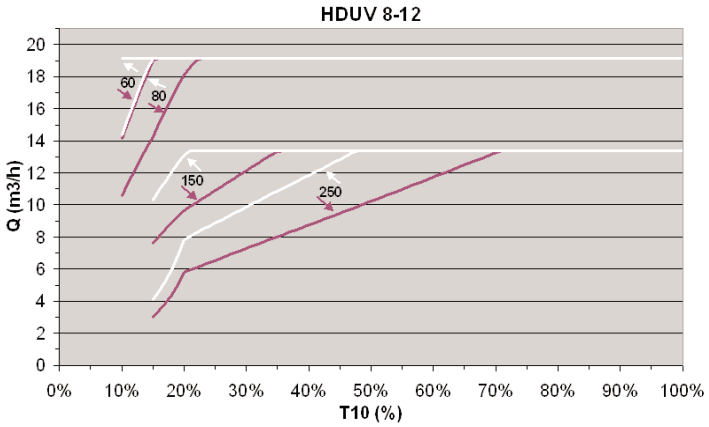

Figure 2: Capacity curves for Vialux 8-12
Water layer 18mm – Lamp length 1 m – Lamp power 12kW
T10 ≥ 10% (fungi, nematodes) T10 ≥ 15% (viruses)
White line valid for new lamp, purple line valid for lamp at end of life cycle

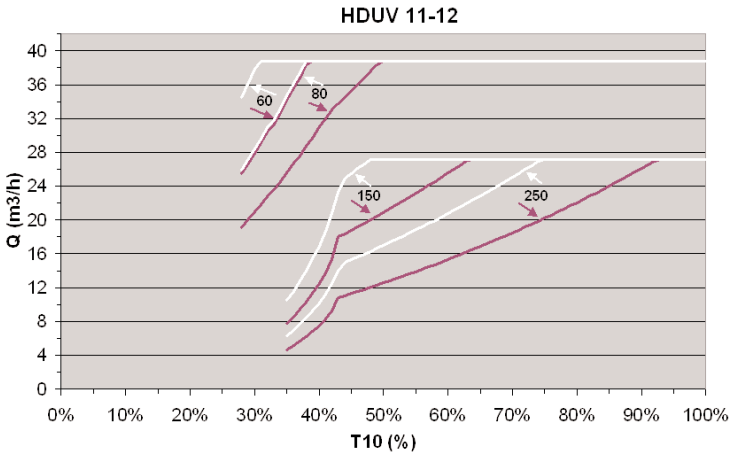

Figure 3: Capacity of Vialux 11-12
Water layer 31mm – Lamp length 1 m – Lamp power 12kW
T10 ≥ 28% (fungi, nematodes) T10 ≥ 35% (viruses)
White line curves valid for new lamp, purple line curves valid for lamp at end of life cycle

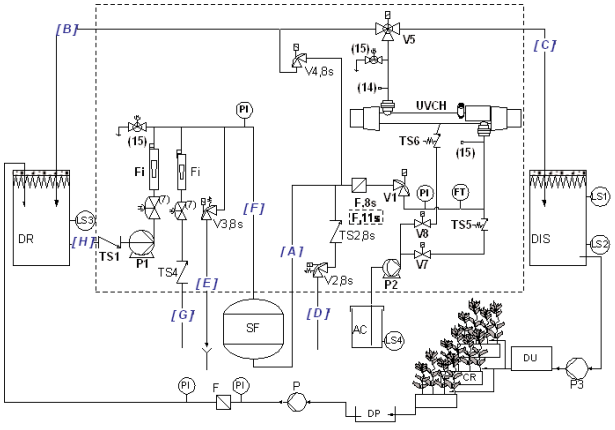

Figure 4: Vialux HD/UV schematic diagram of water system

Total installation around a Vialux includes a tank for "dirty" drain water, a filter with back wash set up, a tank for treated water and obviously pipe work. As example **Figure 4** shows a typical schedule.

And **Figure 5** shows an ideal total water system in horticulture. The water emission can be reduced to practically zero by proper and safe recirculation.

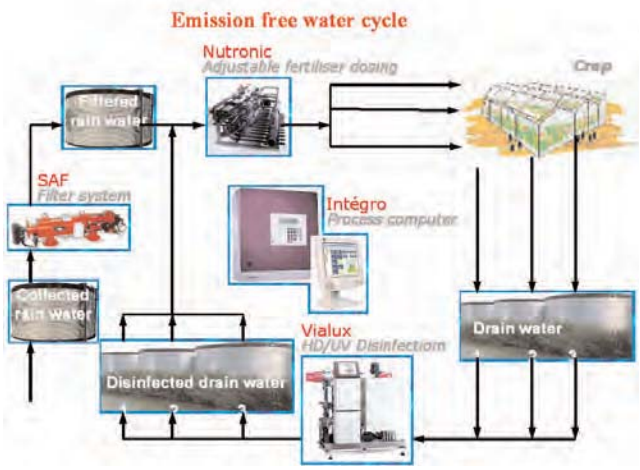

Figure 5: Emission free water cycle in horticulture

CONCLUSIONS

Priva Vialux MP UV disinfection enables horticulture to meet possible future legal requirements for reuse of drain water. Recirculation of drain water saves costs for water and especially fertilisers, and environmental contamination can be reduced strongly. Spreading of pathogens through the water is prevented effectively and economically.

Combination of MP UV with hydrogen peroxide (advanced oxidation) is promising for elimination of residues of pesticides and may improve plant growth.

ACKNOWLEDGEMENTS

Most of the reported work has been set up, planned and supervised by my predecessor at Priva, Drs. Sije Boonstra. Only part of his work has been published.

REFERENCES

1 An overview can be found in the document from the U.S. Environmental Protection Agency, Ultraviolet Disinfection Guidance Manual Final, EPA 815-R-06-007, November 2006 – obtainable via www.epa.gov/safewater/disinfection/lt2/compliance.html

2 W.T. Runia, S. Boonstra, "UV-Oxidation Technology for Disinfection of Recirculation Water in Protected Cultivation", Acta Horticulturae 644 (2004) presented 2nd International conference on the alternative control methods against plant pests and diseases, Lille – 4, 5, 6 and 7th March 2002.