UV for sterilisation of water for soilless systems (I)

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Ultra-violet radiation (UV) has become one of the most popular water disinfection methods for advanced greenhouse horticulture. It is very effective when used in the right way, and it is safe and convenient. Although it is not cheap, it is considered more economic than most other methods. A good UV installation has automatic safeguarding, monitoring and cleaning features built in. Some servicing and maintenance is needed though. In this article we describe the technique and summarise the recommended UV doses. In following articles we will discuss the recommendations in detail, as well as differences between various UV systems.

Principles of UV treatment
Ultra-violet (UV) is an invisible and very hazardous type of radiation. UV does not directly kill, but it damages the DNA of living organisms. UV-C with a wavelength of between 200 and 280 nm is germicidal (destroys germs), with UV of 254 nm being most effective. When water flows along a UV-C source, any pathogen (bacteria, fungus spore, virus, nematode etc.) in the water will be destroyed, provided they receive sufficient UV-C. The UV-C source is a long tube-shaped lamp. Most UV-lamps are low-pressure mercury vapour lamps, but there are also high-pressure lamps, which are sometimes called medium-pressure lamps. The difference between lamp types will be discussed in a following article.

Techniques of UV treatment
An UV steriliser contains one or more UV lamps placed inside quartz tube(s) or sleeve(s), all placed in a stainless steel housing. Water to be treated flows alongside the quarts tubes ir sleeves. Alternatively, some systems have the UV lamp(s) placed outside the sleeve(s) and the water flowing through the sleeves. Such systems sometimes use Teflon rather than quartz sleeves. The UV dose received by the pathogens in the water depends on a number factors:

- strength of the UV lamp(s)
- penetration of UV radiation (transmission)
- flow rate of the water
- thickness of the water layer
- turbulence

All these factors should be taken into account in the design of a UV installation. For example, when less powerful UV lamps are used, the flow rate should be lower, to ensure a sufficient dose. Likewise, when the penetration of UV radiation is low, either more UV should be supplied and/or the flow rate should be reduced. However, the flow rate should be high enough to ensure good turbulence (whirling) of the water. Some UV installations come with a table showing a range of transmission factors and flow rates and the resulting UV dose received by the water. The user can then adjust the flow rate to obtain the required UV dose.
The output (strength) of the UV lamp depends on the lamp type, condition and ‘cleanness’. Obviously the lamps emit less radiation when they are stained or old. Also the temperature of the lamp during operation can be important.

Drain water or raw water
UV sterilisation is usually applied to drain water before that is re-used or recirculated. Drain water, being surplus nutrient solution leaching from the plants, contains fertilisers as well as organic contamination from the plants and the growing medium. Sometimes the drain water contains so much dissolved matter that UV radiation can’t get through (in other words, that the transmission is too low). Then UV-sterilisation cannot be used, or only with special measures (see under ‘Transmission’).

There are places where also the raw water contains pathogens. UV treatment can be applied also to the raw water before that is used to make up the nutrient mix, but the volume of raw water is much bigger (about 3-5 times) than the volume of drain water. On the other hand, raw water is usually clearer than drain water and hence easier to disinfect. In this article 'water ' can mean raw water or drain water.

Pre-filtration

Before any treatment is applied to drain water, it must be filtered very accurately, preferably in several steps. The first, coarse filtration removes plant parts and other debris. Rotten roots are potentially loaded with pathogens, and can even contain the hard-to-kill survival spores of some diseases. So they need to be removed.
Then a fine filtration removes as much as possible the smaller particles. These would shield the pathogens, or in other words pathogens could hide behind debris particles and stay out of reach of the UV beams. Ideally particles of 10 micron should be filtered out by using a 10 micron filter. In practice, however, a 30-micron filter is already rather fine, and some recommendations say a 70-micron filter is good enough. Of course a finer filtering is more effective, but is also more expensive and the clogging will be worse. Finer filters need more frequent back-washing or replacing. In the Netherlands it has become quite common to use a combination of UV radiation and a 'biofilter' or 'slow sand filter' (see following article). But even the finest filtration cannot remove dissolved solids that block the UV and reduce the transmission.

Transmission

The UV radiation must penetrate into the water to destroy all pathogens. Therefore the water must be sufficiently clear. However, this is not 'clearness' that can be observed visually. The water can look absolute clear, but it at the same time can completely block the UV radiation. Especially big amounts of organic molecules or iron chelate reduce the UV penetration. Hence the transmission has to be measured in the laboratory. The water sample is put in a quartz cell of 10 mm width and placed in a spectrophotometer. This sends UV-C radiation through the water sample, and a sensor at the other side of the cell measures the UV-C coming through. The percentage of UV-C passing through 10 mm of water is called the T10, or transmission factor, or %-transmission. Distilled water has a transmission of 100%. Drain water can easily have a transmission below 10%.
Most systems are designed for transmission of at least 20%. Some smaller UV-systems can only deal with water with a higher transmission factor, and only a few very powerful systems can cope with transmission lower than 20%. When the transmission gets lower, the UV source and/or the flow rate are adjusted. However, when the transmission is below a minimum transmission (e.g. 20%), then the UV source and/or flow rate cannot be adjusted further.
To overcome this, the drain water can be mixed with very clear (raw) water. This means dilution of particles and improvement of the transmission. This dilution with clean water also means a loss of efficiency of the treatment.
The transmission of drain water can vary over a day. It is best to collect the drain water in a 'dirty water tank' and to pump it from the tank through a UV steriliser. This makes an even flow, and makes that the transmission becomes more homogeneous.

Units and recommended dose

The UV dose actually received by the water is expressed in mJ/cm^2 or in mWs/cm^2, which are both the same (with J=Joule, W = Watt, s=second, J = Ws). Some publications use µ (micro) instead of m (milli), and then the numbers are 1000 times higher. For instance 100 mJ/cm^2 equals 100 mWs/cm^2 and is also equal to 100.000 $\mu J/cm^2$ and 100.000 $\mu Ws/cm^2$.

The recommended dose will be the topic of next article, but we summarise the basics here. The practical recommendations for pathogen control in (drain) water are: **100 mJ/cm^2 UV-C** for water that contains no viruses, and **250 mJ/cm^2 UV-C** for water containing plant viruses (this is with the transmission taken into account). These guidelines are based on work by Runia in the Netherlands and are proven by thousands of growers worldwide.

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