Bio-filters and slow-sand-filters for soilless cultures

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Sand filtration has been used since two centuries for purifying drinking water, and since many decades for preparing good irrigation water for greenhouse horticulture. In the eighties and nineties, we saw the emergence of 'slow sand filters' also called 'biofilters' in the Netherlands and other countries. They became a common water treatment technique in soilless cultures to remove pathogens from irrigation water or from run-off. Slow sand filters are effective against Phytophthora and Pythium, but not against most other pathogens. In this article we discuss the bio-action of such filters and some technicalities of slow sand filters. In the following article we look at biofilters in more detail.

How biological is a 'biofilter'
The word 'biofilter' should be used for filters that operate with a biological mechanisms, e.g. through good bacteria fighting with bad bacteria. Various types of filters work biologically. In the Netherlands the word biofilter is also used for a slow sand filter. It is not certain that there is always a biological effect with these filters. Slow sand filters have in the first place a mechanical effect: disease spores are hold back by the filter. Some disease spores (of Pythium and Phytophthora) die in the filter bed. Possibly they are destructed by micro-organisms (which is a biological action). However, some disease spores don't die at all in the filter bed, and they can come out of the filter alive. For these spores the filter is not effective. So the working of a slow sand filter is mostly based on a mechanical action, possibly enforced by a biological action. The extent of a biological effect depends on a lot of factors, and it can be more developed in one filter than in another. The word biofilter is sometimes used too loosely.

Build-up of a slow sand filter
The slow sand filter is similar to a normal sand filter, but the difference is that the flow rate is considerably lower and the filter bed considerably finer than with the conventional sand filters. Hence a slow sand filter must be much larger than a normal sand filter. They are more prone to clogging and need more maintenance than normal sand filters. A slow sand filter basically consists of the following parts from top to bottom: (1) water layer; (2) filter bed, (3) drainage system and (4) flow control system.

<u>(1). Water layer</u>
A layer of 'dirty' water stands on top of the sand bed. This water column acts as water storage (buffer) and also provides the pressure ('head') to push the water through the filter bed. The water column allows sedimentation of heavy particles. The recommendation is a water layer of between 1 and 1.50 m on top of the filter bed. In practice, the water layer is often only 0.5 m thick. A constant height of the water layer helps to achieve a fixed flow rate. In practice, the water height varies due to the variation in the amount of dirty water awaiting treatment, and hence the flow rate may vary too.

<u>(2). Filter bed</u>
The filter bed consists of a sand layer of 0.8 m (minimum) to 1.2 - 1.4 m (recommended). An absolute minimum of the sand layer is 0.4 m. The sand layer will decrease because the upper 20-30 mm will be scraped off regularly in cleaning operations. When the sand bed gets too thin, it must be topped up. If additional protection against diseases is required it is best to increase the depth of the sand bed rather than to reduce the grain size.

Sand quality
Researcher Erik Van Os in the Netherlands tested various sizes of sand and recommended the use of fine sand (0.15-0.35 mm). Too coarse sand is not effective. Too fine particles decrease the filter run, and the filter needs to be cleaned more often. The sand should be of excellent uniformity. When the particles vary in size, then the larger particles will be driven deeper into the sand, and the top will consist of finer sand. This increases the clogging, so that more sand needs to be scraped off during cleaning. It is important that the filter sand is free of loam, clay and organic matter. Washing the sand before use will remove the finer particles and improve the uniformity.

(3). Drainage system
Mostly two layers of gravel are put under the sand bed to provide free drainage and to avoid flushing of sand into the outlet. A top gravel layer of 0.1 - 0.4 m with a grain size between 2 and 7 mm is recommended to realise a smooth change between the fine sand and the coarse gravel. The bottom layer of 0.1 - 0.2 m consists of a coarse gravel of approx. 7-15 mm grain size. This bottom layer of gravel contains perforated drainpipes leading to a main drain.

(4). Flow control system
In the outlet of the filter, a regulating tap controls the flow rate. This outlet is also used to maintain submergence of the sand layer under all conditions. An open pipe is connected to the outlet to measure the water pressure and to get an indication when head loss occurs. Head loss is the loss of pressure when the top layer of the sand bed is blocked. Then there is still water on top of the filter bed, but it does not put pressure on the water in the filter bed.

Flow rate
A slow sand filter requires a really slow flow rate, which is always very frustrating for growers. Hence they increase the flow rate, which of course reduces the efficacy. The recommendation is a flow rate of 100 $l/m^2/h = 0.1\ m^3/m^2/h = 0.1\ m/h$ (Van Os). With this flow rate, and with the filter operating 20 hours per day, only 2 m^3 water passes the filter per m^2 filter area.

Required size
Due to the slow flow rate, the slow sand filter must be huge in size. We calculate the required filter area to treat the run-off from one acre and from one hectare of greenhouse area. We assume that the run-off is 2 litre/m^2/day. This equals 2 m^3 per 1000 m^2 greenhouse per day or 8 m^3/acre/day, etc. Because 1 m^2 filter area can treat 2 m^3 water per day (20 hours), we need 1 m^2 filter area per 1000 m^2 greenhouse area, or 4 m^2 filter per acre greenhouse, etc.
To calculate the volume of a sand filter, we assume that the filter bed is 1 m thick. To calculate the weight, we use the average weight of sand, which is 1600 kg per m^3. Treating the irrigation water requires an even bigger size filter. As an example we calculate the required filter size at a water consumption of 5 litre/m^2/day. The calculated area, volumes and weights of the filter bed are shown in the table.

Filling the slow sand filter
A new slow sand filter must be filled from the bottom upwards, and the rate of filling must be lower than the recommended flow rate (lower than 0.1 m/h). After filling the filter needs several weeks to mature (with water in it or flowing through). It is assumed that micro-organisms can develop and establish themselves in this period. If the filter is unused for a couple of weeks, it has to be left filled with water.

Clogging / maintenance
Clogging is the common problem with slow sand filters. Clogging closes the filter skin (surface of sand bed), which blocks the water flow through the sand bed. It can show as a crust with a dark green or brown colour on the filter skin. Algae are probably one of the causes of the clogging. Also deposition of nutrients due to pH changes may contribute to clogging. Clogging occurs more in finer sand and at higher flow rate.

Indications that clogging is imminent are a reduction in pressure that can be seen in the open pipe. When clogging happens, the water does not increase when the tap opens further. Clogging can be fixed by scraping a few mm of sand and removing the top 20-30 mm of the sand bed. Most users of slow sand filters experience clogging once in two to four months. It is a nuisance, but not a serious problem.

Efficacy
It is generally accepted that slow sand filters are effective against Pythium and Phytophthora, but not satisfactorily effective against other pathogens. In practice, most growers in the Netherlands have placed an UV steriliser after the slow sand filter (see next article).
It is recommended to have two slow sand filters instead of one. This enables the grower to run the slow sand filters at the low speed as required, and to reduce the risk of pathogens trickling through. Also, if one filter is clogged, the other can be used. In the next article we will discuss the efficacy and some practical aspects of using slow sand filters and biofilters.

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TABLE. *Calculated area, volumes and weights of the filter bed of a slow sand filter. Assumptions: amount of drain water is 2 litre/m^2/day, amount of irrigation water is 5 litre/m^2/day, the filter treats 100 litre/m^2/hour, and runs 20 hours per day.*

	treating drain water or run-off			**treating irrigation water**		
	per 1000 m^2	**per acre**	**per ha**	**per 1000 m^2**	**per acre**	**per ha**
water volume (m^3/day)	2	8	20	5	20	50
filter area (m^2)	1	4	10	2.5	10	25
filter volume (m^3)	1	4	10	2.5	10	25
sand weight (tonne)	1.6	6.4	16	4	16	40