# PROSPECTS OF SLOW SAND FILTRATION TO ELIMINATE PATHOGENS FROM RECIRCULATING NUTRIENT SOLUTIONS

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## Abstract

In closed soilless growing systems there is a risk of spreading root pathogens over the nursery. Existing disinfection methods, such as heat or ozone treatment are rather expensive. Therefore, application is hardly feasible on nurseries smaller than 1 ha. Slow sand filtration may be an alternative to eliminate root pathogens. Aim of the experiments was to investigate the requirements at which slow sand filters have to meet for practical application in horticulture.

Six treatments, namely three sand types (coarse, 0.5-1.6 mm; middle 0.2-0.8 mm; fine 0.15-0.35 mm, with an effective size of 0.71 mm, 0.51 mm and 0.23 mm, respectively) and two filtration rates (0.1 and 0.3 $m^3.m^{-2}.h^{-1}$) were compared in two replicas in separated closed systems growing tomatoes in rockwool. Effectiveness was tested by inoculating *Phytophthora cinnamomi, Fusarium oxysporum* f.sp. *Lycopersici* and tomato mosaic virus. In addition, physical (EC, temperature) and chemical (COD, $BOD_5$, $NH_4^+$, $NO_3^-$, pH and oxygen concentration) parameters were measured.

*P. cinnamomi* was filtered out completely at the filters with the fine and middle grain size at a filtration rate of 0.1 $m^3.m^{-2}.h^{-1}$ while it passed through all other filters. *Fusarium oxysporum* f.sp. *Lycopersici* and tomato mosaic virus could be detected in the effluent during a long period. Both pathogens were only retarded. Neither physical nor chemical parameters were influenced by the flow rate or the grain size. Only small differences between influent and effluent could be measured for $NH_4^+$ and oxygen concentration.

## 1 Introduction

In 1804 in Scotland John Gibb developed the first slow sand filter installation for his bleachery to obtain pure water (Ellis, 1985). His design was improved and Slow Sand Filters (SSF) were used by water companies to purify river water for drinking purposes. As advantages Ellis (1985) mentioned simple operation, removal of nearly all turbidity as well as organic material, improvement of the colour and, more important, removal of pathogens such as bacteria and viruses. Disadvantages are the large area requirements, costs of cleaning after clogging and the chance for clogging as a result of the high turbidity of the water.

Until recently SSF was only used for water treatment for drinking water purposes. Looking at the advantages of SSF, application of this method for the removal of pathogens from recirculation water or waste water in (glasshouse) horticulture shows perspectives. In glasshouse horticulture where flowers and vegetables grow on substrates, the superfluous nutrient solution has to be recirculated to avoid

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contamination of ground and surface water (Van Os, 1995). Alternative methods for disinfection of the recirculation water are described by Runia (1995). Common problem of most methods is the high costs of investment. It makes disinfection methods economic feasible only at nurseries of more than 1 ha. On the other hand there are many small nurseries in the Netherlands facing future legislation with the obligation to recirculate the nutrient solution. Besides, most of European nurseries are also smaller than 1 ha, the tendency can be seen of changing to closed soilless growing systems as well. SSF may be a solution for growers in glasshouse horticulture, but also for growers in arboriculture and the forcing of witloof chicory.

Initial research of SSF was done in arboriculture (Wohanka, 1991; Friedel et al., 1991) and the first practical applications of SSF in glasshouse horticulture have been based on this work.

In 1993 Van Os et al. proved the economic feasibility of SSF in glasshouse horticulture as a method for removing pathogens from recirculation water. At the same time Van Kuik (1994) proved the possibilities for elimination of *Phytophthora cinnamomi* by SSF in nursery stock. The positive results led to further investigations on working conditions and working mechanisms of SSF. In this paper results of the research are presented.

## 2 Material and methods

### 2.1 Aim of the experiment

The aim of the experiment was to find:

- the requirements on which slow sand filters have to meet for practical application in horticulture;
- the working mechanism of elimination of plant pathogens from the recirculation water.

### 2.2 Treatments

As experimental treatments, to realize the mentioned aims, two flow rates and three sand types with a different grain size were installed in iteration in the sand filters. The two filtration rates were 0.1 and 0.3 $m^3.m^{-2}.h^{-1}$ (= $m.h^{-1}$). The three sand types were coarse (0.5-1.6 mm), middle (0.2-0.8 mm) and fine (0.15-0.35 mm). The coarse grain size is widely used by growers. The fine grain size is mostly recommended in literature (Ellis, 1985; Collins & Graham, 1994) for purification of drinking water.

In a glasshouse department of 300 $m^2$ at IMAG-DLO 12 slow sand filters (SSF) were placed. Each PVC filter, 15 cm diameter, (Figure 1) was connected to one row of tomato plants, growing in rockwool, covering an area of 20 $m^2$. Drainwater of one row of tomato plants was pumped to the upper container of the sand filter. This container was used to obtain a larger storage capacity than available in the filterpipe. From the upper container the drainwater flew to the filter, trickled through the sand bed, passed a flow meter for controlling the flow rate and was collected in the lower container. From this container the water was pumped back to the plants. In the lower container fresh nutrient solution was added to compensate the uptake of nutrient solution by the plants.

The sand filter bed had a depth of 80 cm and was placed on two thin layers of gravel, 10 and 15 cm, respectively. The physical properties of the sand types used were measured and given in table 1. On top of the sand bed a water layer of 100 cm was standing. In the outlet of the filters a flow meter had been installed. Besides, an open pipe was connected to the outlet to measure the headloss.

### 2.3 Analysis

Between April and December 1995 biological, physical and chemical parameters were measured. In that period the elimination of the inoculated root pathogens *Phytophthora cinnamomi, Fusarium oxysporum* f.sp. *lycopersici* and tomato mosaic virus was also measured. These three pathogens were chosen for practical experimental reasons as well as horticultural reasons. Results for *Phytophthora cinnamomi* are also valid for pythium species as they belong to the same family.

In two experiments zoospores of *Phytophthora cinnamomi* (Pc) were added to the influent of the filters, $0.9 \times 10^6$ and $1.0 \times 10^6$ spores in a 25 ml and 40 ml solution , respectively, to each filter. For three days the effluent of each filter was collected in a tank to detect Pc by using a bait. Ten *Rhododendron* 'Catawbiense' leaf disks were immersed in the effluent and after three days transferred to a selective medium for phytophthora ($P_5$VPH), slightly modified after Tsao & Guy (1977). The agar plates were incubated for three days at 25°C, after which the leaf disks were examined for infection of Pc. The effluent was collected and tested for Pc for fifteen days. During the experiments the filters were disconnected from the growing system.

The performance of the filters against *Fusarium oxysporum* f.sp. *lycopersici* (Fol) was tested in two experiments. Approx. $1.0 \times 10^5$ microconidia were added to the influent. Water samples of influent and effluent were plated out on the selective Komada-medium (Komada, 1975) in quadruplicate with 0.5 ml per agar plate. The plates were incubated for seven days at 20°C, after which Fol colonies were counted. Initially samples were collected for three days. In the second experiment, samples of the effluent from three filters were taken, every week, up to 120 days after inoculation.

Tomato mosaic virus was also tested in two experiments. For this, 1 ml virus suspension was added to 1 l recirculation water in each filter.The infectivity was tested in a bioassay. Water samples were rubbed on leaves of *Nicotiana tabacum* 'Xanthi'. After three days local lesions could be counted on the leaves. Per treatment, three leaves were inoculated on each of three plants. In the first experiment the effluent was collected for three days, in the second for six days.

EC (mS/cm, 25°C; Elmeco PHM-01 handmeter), pH (WTW LF 96 handmeter), temperature, oxygen concentration were measured in the influent and the effluent on a weekly base. Chemical oxygen demand (COD), biological oxygen demand ($BOD_5$), ammonia and nitrate concentration (analysis following the Dutch Institute for Standardisation, 1988) were measured when pathogen inoculation of the filters took place.

Tomato plants were planted in December 1994. The slow sand filters were connected to the plants from April 1st to December 8th 1995. The filters were allowed a four weeks ripening period after connection, permitting the development of an optimal biological activity. There was no addition of products to stimulate biological growth.

## 3 Results and discussion

### 3.1 Biological measurements

In both experiments, *Phytophthora cinnamomi* was not detected in the effluent of the filters with fine and middle sand in combination with the low flow rate. The combination of the high flow rate and middle and coarse sand Pc passed the filters and could be detected. The low flow rate with coarse sand and the high flow rate with fine sand showed variable results in the two experiments. After nine and twelve days no Pc could be detected in either of the filters.

*Fusarium oxysporum* f.sp. *lycopersici* could not be detected in the first three days after inoculation. The weekly samples for a period of 120 days proved that the behaviour of Fol was quite different. In total more than 40% of the influent concentration could be detected.

The results with Tomato mosaic virus were similar to Fol. After three days the elimination rate looked satisfactorily high, but in measurements after that period ToMV could be detected in the filters with the high flow rate for two weeks. In the filters with the low flow rate ToMV was detected for a shorter period.

### 3.2 Physical measurements

EC, pH, oxygen concentration and temperature were measured weekly during the growing season. They all show very small differences between the 12 filters and between influent and effluent. There is also hardly any difference in temperature between influent and effluent, but a small significant difference in oxygen concentration of 1-2 mg/l could be distinguished. Here, the effluent concentration is lower than the influent concentration, especially in the period from April to July. This may be caused by biological activity. The influent flow has oxygen concentrations near the saturation point. Because the oxygen concentration in the effluent was also rather high (6-7 mg/l), the total aerobic biological activity in the filters is low. The absence of a lower oxygen concentration in the effluent between July and November may be caused by disturbance of the microbiological activity by fluctuating pH-values in July.

### 3.3 Chemical analyses

Table 2 shows mean values of COD, $BOD_5$, $NH_4$ and $NO_3$. There were no differences between grain size or flow rates, except for $NH_4^+$ in the effluent. At the 0.1 $m.h^{-1}$ filtration rate ammonium concentrations were lower compared to 0.3 $m.h^{-1}$ filtration rate. This may be caused by nitrification of ammonium to nitrate.

The reason for the low biological activity of the filter must be sought in the relative clean influent. As organic contamination is very low only autotrophic growth in the filters is promoted. This could be seen at low flow rates where removal of $NH_4^+$ indicates the growth of nitrifiers.

### 3.4 Clogging and cleaning of the filters

Clogging of one of the filters appeared five times during the season. The first time after 57 days, the filter showed a crust on the sand surface and had a dark brown colour. The other cloggings were after 217, 218, 302 and 308 days after connection of the filters to the plants and showed a dark green to brown Schmutzdecke (= filter skin). Algae may be the cause of these last cloggings. Four of the five cloggings appeared in the filters with fine sand and the 0.3 $m.h^{-1}$ filtration rate. The fifth was in the filter with middle sand and the high filtration rate.

Clogging could easily be predicted by measuring the headloss by connecting an open pipe above the flow meter parallel with the filter pipe (Figure 1). After clogging the filters were cleaned by scraping off the Schmutzdecke and a few millimeters of sand. Immediately after scraping the flow rate was restored and headloss was marginal.

## 4. Conclusions

Three sand fractions (Effective Size is 0.71 mm, 0.51 mm 0.23 mm, respectively) and two filtration rates (0.1 and 0.3 $m.h^{-1}$) were compared with each other to determine

the effectiveness of slow sand filters in a system growing tomatoes on rockwool with recirculation of a nutrient solution.

*Phytophthora cinnamomi* could be eliminated at a filtration rate of 0.1 $m.h^{-1}$ and a sand fraction with an effective size less than 0.5 mm. *Fusarium oxysporum* f.sp. *lycopersici* and tomato mosaic virus could not be eliminated effectively. From these results, slow sand filtration can only be recommended for crops which are only threatened by phytophthora or pythium species.

Neither the flow rate nor the sand fraction seem to influence the physical (EC, turbidity and temperature) and chemical (COD, BOD, $NH_4^+$ and $NO_3$-, pH and oxygen concentration) contents of the nutrient solution dramatically. Results for influent and effluent vary only slightly for ammonium at the low flow rate and oxygen concentration for part of the season. Clogging of the filters did not appear very much. It can easily be measured by measuring the headloss and it mainly occurs in the fine sand filters at a high flow rate.

Both, the small difference for $NH_4^+$ concentration and the absence of clogging indicate a low biological activity in the filters.

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Table 1: Characterization of the sand fractions.

| sand type | diameter (mm) | ES($d_{10}$) (mm) | $d_{50}$ (mm) | $d_{60}$ (mm) | $d_{90}$ (mm) | UC (=$d_{60}/d_{10}$) | s.w. ($kg.l^{-1}$) | porosity % |
|---|---|---|---|---|---|---|---|---|
| coarse | 0.5-1.6 | 0.71 | 1.06 | 1.11 | 1.33 | 1.57 | 1.72 | 33 |
| middle | 0.2-0.8 | 0.51 | 0.62 | 0.62 | 0.75 | 1.27 | 1.71 | 34 |
| fine | 0.15-0.35 | 0.23 | 0.29 | 0.30 | 0.37 | 1.33 | 1.58 | 35 |

Table 2: Mean values of biochemical and chemical oxygen demand, ammonium and nitrate concentrations in influent and effluent of the sand filters (5 measurements; standard deviations between brackets).

| | flux $m^3.m^{-2}.h^{-1}$ | grain size | COD $mmol.l^{-1}$ | $BOD_5$ $mmol.l^{-1}$ | $NH_4^+$ $mmol.l^{-1}$ | $NO_3^-$ $mmol.l^{-1}$ |
|---|---|---|---|---|---|---|
| in | all | all | 0.61 (0.18) | 0.10 (0.04) | 0.15 (0.09) | 17.3 (-) |
| out | 0.1 | fine | 0.78 (0.09) | 0.15 (0.09) | 0.07 (0.10) | 20.8 (5.5) |
| | | middle | 0.79 (0.16) | 0.34[1)] | 0.05 (0.08) | 21.1 (6.4) |
| | | coarse | 0.73 (0.24) | 0.12 (0.06) | 0.04 (0.06) | 22.7 (7.3) |
| out | 0.3 | fine | 0.70 (0.13) | 0.11 (0.02) | 0.12 (0.08) | 18.3 (2.8) |
| | | middle | 0.71 (0.10) | 0.12[1)] | 0.12 (0.09) | 19.2 (3.2) |
| | | coarse | 0.64 (0.12) | 0.08 (0.04) | 0.14 (0.09) | 18.3 (2.7) |

[1)] only one measurement

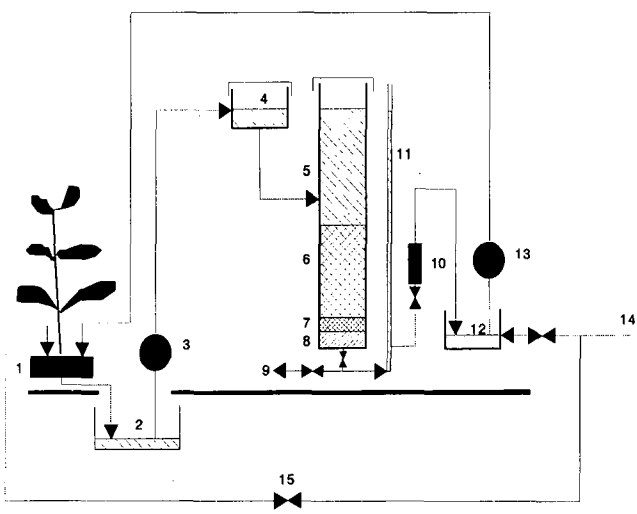


Figure 1: Principle of slow sand filtration. Nutrient solution drains from substrate 1 to recatchment tank 2. From there it is pumped (3) to upper container 4, from which it flows to the sand filter. 5 is the supernatant water layer of 1 m. Between 5 and 6 the filter skin or Schmutzdecke and 6 is sand. 7 and 8 are the 10 and 15 cm gravel layers, respectively. Tap 9 is for initial filling of the filter. Flow meter 10 controls the filtration rate. Open pipe 11 measures the head loss. Container 12 collects the filtrate and mix it with fresh nutrient solution 14. From there pump 13 supplies the solution to the plants. During maintanance valve 15 is open and supplies the plants with fresh nutrient solution, excluding the use of the sand filter.