Horticultural
Development
Council

Slow Sand Filtration

Installation, operation & maintenance

A grower guide

A flexible, economic biofiltration method for cleaning irrigation water

This guide aims to introduce the components of a Slow Sand Filtration System, explain how each component works and outline the considerations that must be taken into account when planning on installing such a system.

It has been written by Tim Pettitt, formerly of HRI Wellesbourne, now based at the Eden Project, with input from Dave Hutchinson of ADAS.

Considerable time and effort has been spent by Tim distilling the key points from several years of HDC and Defra funded research. These have been coupled with robust practical recommendations to produce this comprehensive grower guide.

Our thanks are due to Paul Masters of Notcutts Nurseries and John Adlam, Dove Associates for their valued contributions to this guide.

Foreword

The importance of quality water to growers for container production and protected cropping has never been more acute. Increasing restrictions on the availability of water for irrigation due to climatic and political influences, plus rising costs are leading many growers to look carefully at their water consumption and consider alternative sources, such as runoff, from their nurseries.

As an industry and as individual growers, we must plan ahead to ensure that we have adequate supplies to produce products that meet and exceed, the expectations of our customers.

The opportunities to collect rainfall and irrigation run-off exist on most nurseries, both large and small. Nevertheless, the motivation to re-cycle is often not solely economic when set against the prospect of increased pressure on ground water supply.

To be of use for plant production recycled water must be free of aggressive plant pathogens eg *Phytophthora* and *Pythium* spp. Slow sand filtration (SSF) is one of a number of methods that can be effectively used to treat water to remove plant pathogens. When well planned and maintained, it can provide a valuable contribution to the total annual water requirements of the nursery, significant cost savings on mains water supply and a contribution to the environment through the more efficient use of irrigation water.

It is important to select the correct water treatment and the wide diversity of our industry means that different nurseries have different choices. SSF is very flexible in terms of size and design and its comparatively low cost makes it an attractive water treatment option. In this growers' guide, Tim Pettitt from the Eden Project puts slow sand filtration into context and relates the considerable R&D work carried out by Defra and HDC on treating irrigation water, commercial design and monitoring procedures. Also, David Hutchinson, ADAS gives guidance on the experience to date in the field with information on planning, design and specification of materials, the construction and operation experience, with an estimate of costs.

I recommend this growers' guide to all who are planning ahead to ensure their production units have a plentiful supply of water which is disease free and recycled with due regard to the environment, ensuring quality plants and the continued employment of staff together with the growth and prosperity of the horticultural industry.

Paul J Masters
Notcutts Nurseries

Fig 1

View of Notcutts Nurseries slow sand filter

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Background

What are slow sand filters and how do they work?

SSF is a form of bio-filtration and the type shown in this guide has been used world-wide for drinking water production for nearly 200 years. Essentially it consists of a column of sand through which the water to be treated is passed at a comparatively slow rate. A biofilm layer is formed on the surfaces of the sand grains in the filter and it is this that kills and consumes pathogen spores that have been slowed down or trapped by the sand. The efficacy of SSF against plant pathogens is dependant on encouraging the growth and activity of this biofilm layer.

What other components make up the complete SSF system?

A slow sand filtration set-up consists of four basic parts (Fig 2), of which the filter (sand column) is just one. The other parts include:

1. A collection reservoir or continuous source of raw water to be treated.
2. A system for pre-treating the raw water to remove most of the suspended fine particles that would rapidly clog the SSF.
3. (The SSF sand column).
4. Storage reservoir(s) or tank(s) for clean water ready for use.

What are the benefits of a SSF system?

The main benefits of SSF are that it:

- Widens the choice of safely usable sources of irrigation water by enabling pond, river, roof and production run-off to be used.
- Effectively and reliably removes plant pathogens from irrigation water, providing a continuous supply of good quality water.
- Provides an alternative source of good quality water at times of peak demand.
- Can significantly save on mains water usage, 50% substitution is possible on a typical nursery and 100% if space and capital allow.
- Environmental benefits include reduced downstream pollution, overall reduced water wastage and often reductions in pesticide use.
- Production quality improvements and reduced crop losses.
- Flexible and simple design enables systems to be tailored to individual nursery layout systems.
- Easy to install and maintain.
- Low running costs.

How do SSF compare with other cleaning systems?

SSF is one among a number of water treatment methods that have been demonstrated to be effective at eliminating plant pathogens from contaminated water. The main alternatives are:

- UV - passing ultraviolet radiation through the water.
- Ozonation - bubbling ozone gas through the water.
- Pasteurisation - applying heat.
- Chemical treatment eg dosing with chlorine.

Many of these systems achieve indiscriminate kill of organisms in the water (UV, ozonation, pasteurisation or chlorination). SSF is remarkable in that it involves both physical filtration processes and selective biological activity. There have been suggestions that this selective activity can have a positive effect on the 'biological stability' of systems downstream of treatment and there is also strong anecdotal evidence for disease suppressive qualities of SSF-treated water from UK nurseries in both HNS and protected cropping.

No one treatment technique is perfect for all nurseries and selection of the most appropriate water treatment will depend on a wide range of factors including costs, available space, provisions for expansion, approaches and aims of proposed water management programme. The following table is not exhaustive but gives a rough idea of the advantages and disadvantages of the main effective treatment methods available.

Table 1

Comparison of advantages and disadvantages of the main treatments available for eliminating plant pathogens from irrigation water

Water treatment	Advantages	Disadvantages
SSF	• Flexible and simple design • Easy to install and maintain • Does not use dangerous chemicals • Low running costs • Environmentally friendly	• Filters occupy a comparatively large space • Require regular cleaning • Pre-filtration essential • Treatment process comparatively slow • Expensive to install
UV	• Relatively low capital cost • UV units occupy comparatively little space	• Water must be free of suspended particles - pre-filtration essential • Correct flow rate essential for thorough irradiation • High maintenance with cells requiring regular cleaning • Continuous electrical power supply needed
Pasteurisation	• Known, safe, reliable and robust method for treating water	• Prohibitively high energy costs
Chlorination	• Relatively simple to install • Long record of successful use • Creates an environment hostile to algal growth • Encourages oxidation - helping to break down organic matter and remove iron and manganese • Cleans pipework and irrigation system	• Pre-filtration needed • Most plants are sensitive to chlorine and may be poisoned if injected at high rates • Chlorine solutions are dangerous to humans and animals and must be handled according to COSHH regulations • Risk of organochlorine formation • Chlorine reacts with ammonium so cannot be applied with this form of N fertiliser • pH must be kept to 6 - 7 • Only horticultural grade hypochlorite can be used as other grades contain phytotoxic chlorates • Dosed water must be stored for a time to allow dissipation of chlorine
Ozonation	• Adds oxygen • No noxious products formed	• Not widely used in either UK or mainland Europe • High capital and running costs • Pre-filtration required • Treatment process comparatively slow

Basic components of a SSF system

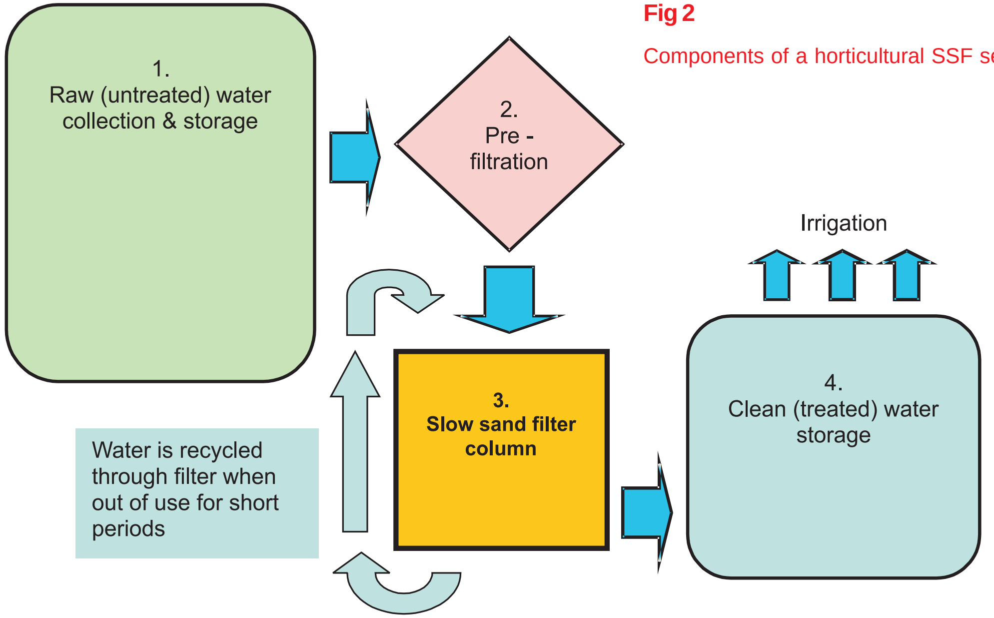


Fig 2

Components of a horticultural SSF set-up

Raw water collection and storage facility

The SSF must never run dry, and whilst it can be run quite satisfactorily in 'recycle mode', it is important to have a reliable source of untreated water, ideally a large holding reservoir. The size of raw water storage capacity is an economic decision and is governed by the capital cost of construction, the space available, the likely volumes and types of raw water available and the volumes required by the nursery.

Types of water that can be collected and stored include rainwater run-off from greenhouse roofs or nursery beds and open reservoir or river water. Rainwater run-off from greenhouse roofs is generally very high quality water but is often contaminated with pathogenic *Pythium* spp., oil deposits from heaters and shading materials. SSF is an ideal method for cleaning this source of water. If raw greenhouse roof water is stored in a covered tank and is not mixed with water from other sources, pre-filtration is not normally required.

Surface-derived water sources (rivers, ponds and nursery bed run-off) all carry high plant disease risks that can also be eliminated by treatment with SSF. These water sources often contain large quantities of suspended particles and will invariably need some form of pre-filtration before SSF treatment.

See HDC factsheet on ‘Recycling water’.

Fig 3

Collection channels placed between production beds channel water to collection reservoir

Fig 4

Raw water collection reservoir

Basic components of a SSF system

Fig 5

Fast sand pre-filters

Pre-filtration

As with other water treatment techniques (eg UV and chlorination), SSF is not designed to remove the coarser debris from dirty water. For SSF to function efficiently it is essential to pre-filter the water to remove the larger suspended fines as these will rapidly clog the sand surface and make it necessary to shut down and clean the filter.

Two levels of information are needed to decide on the approach to pre-filtration. The first is an estimate of the expected particulates load in the raw water. This will indicate whether or not pre-filtration is necessary. For example a raw water source derived largely from greenhouse roof water may have a very low particulates load and therefore not necessitate pre-filtration.

The second level of information is supplied by the size distribution of the particles in the raw water. This information is vital in deciding what type of pre-filtration to use, and in some cases whether SSF or even attempting to recycle water from an individual source will be an economic proposition. For example where raw water contains very large quantities of clay particles less than 30µm (0.03mm) prefiltration should not be considered. Types of pre-filtration range from simple pond/reservoir settlement, cyclone filters to graded sand filters with a backwash facility.

Work in HDC project HNS 88b showed that pre-filtration units capable of removing particles greater that 50µm (0.05mm) were very effective for extending SSF filtration run-times under heavy loadings of suspended particulates. This area is still under practical examination and a factsheet will be produced on the subject in due course.

Slow sand filter column

How do you determine the size of filter required?

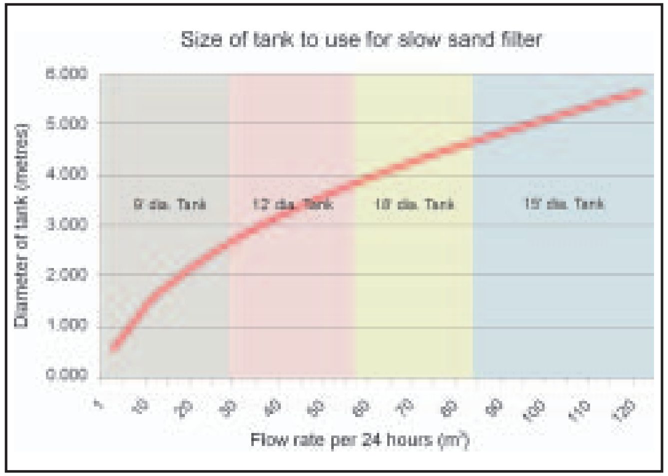
A SSF should be capable of supplying sufficient water in 24h for 24h of maximum demand plus a safety factor/ allowance for expansion of approximately 10%. Water flow through a SSF is measured in meters head per hour above the sand surface (m/h). The design should be based on a conservative flow rate (0.1-0.15m/h) as this will also allow some extra potential water treatment capacity (by up to 100%).

The surface area of filter required to produce the volume of treated water required in 24h of running can be calculated in m^2 by: ((a + b)¸ 24) ¸0.15 = m^2

where a = maximum daily water demand (m^3)
and b = 'safety margin' (m^3).

Fig 6

Graph of increased throughput with filter size



Basic components of a SSF system

A simple 'rule of thumb' is that 1m^2 of filter surface area will produce 4m^3 (1080 gallons) of clean water over 24h having a water head maintained at 0.3m. This flow rate will vary with differing water heads and filter sand quality.

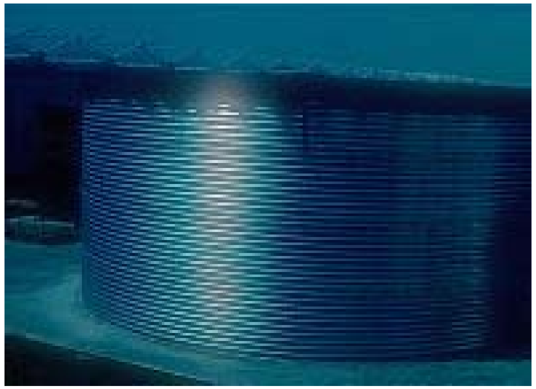
Once the size of SSF required is determined, and a suitable location between storage of untreated and treated water is found, filter design needs to be considered. There is a great deal of freedom here.

What sort of container is suitable for a SSF?

The main consideration for design is the container for the filter. Anything will do for this, so long as it is water-tight and can hold the sand column, allowing easy removal of treated water from the bottom and access to the sand for cleaning operations. A minimum container depth of 1.5m is required to hold sufficient sand and water head above it. The two most widely used approaches to filter design have been, circular butyl-lined corrugated steel water tanks or lined holes dug in the ground. Either technique is absolutely fine and the final decision depends on costs, site suitability and, possibly, local planning authority rulings.

Fig 7

SSF using a corrugated steel tank



What type and depth of sand is needed?

The range of sand qualities suitable for horticultural SSF is quite broad, but best control will be achieved using a uniform, fine, non-calcerous sand that contains no more than 10% by weight of grains smaller than 0.2mm and no more than 10% greater than 1.0mm.

The best way to test the suitability of a sand is to obtain a sieve analysis from your sand supplier (aim for an effective diameter of 0.15-0.30mm and a uniformity coefficient of less than three).

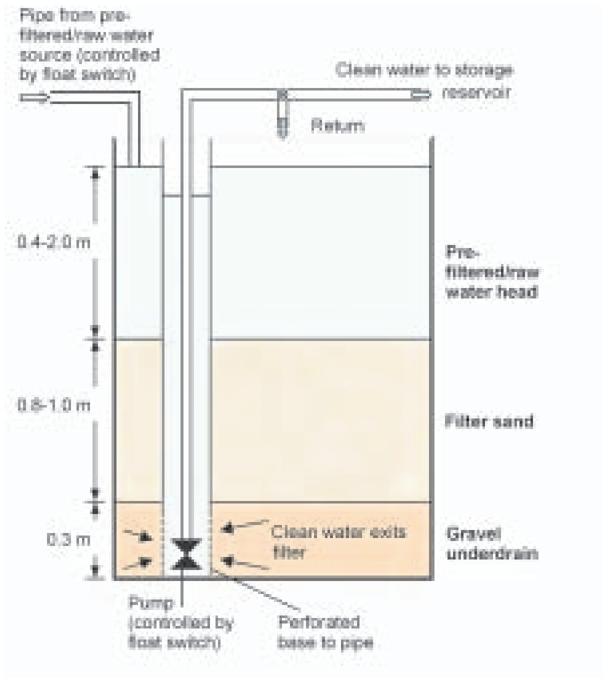
The minimum depth of sand is about 0.5m, whilst the optimum is between 0.8 and 1.0m, which will allow for some cleanup operations.

Fig 8

SSF consisting of a hole in the ground lined with butyl liner

Fig 9

Basic components of a SSF column design



Basic components of a SSF system

Fig 11

Fan of drainage tubes which take water from the bottom of the filter into the large extraction tube

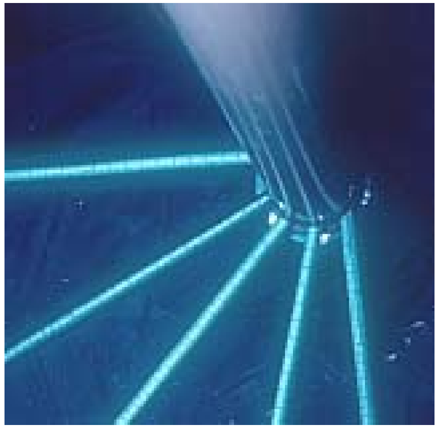


Fig 10

Top of under-drain gravel layer in a filter under construction

What is the role of an under-drain?

This is the layer that supports the sand and into which treated water from the sand column drains. It is most effectively constructed from two approximately 15 - 20cm thick layers of 20mm and 6mm gravel, with the 6mm gravel at the top. The sand layer is placed on top of the 6mm gravel and once it is bedded in, sand should not migrate into the gravel layer. Placing a fabric layer between the sand and gravel is definitely not recommended as it can become clogged with fine inorganic particles.

How do you remove treated water from the filter?

Treated water can be lifted from the filter using a submersible, bore-hole pump controlled by float switches and housed in a drain pipe that has perforated walls in the bottom 25cm or so of its length - the part that goes into the gravel under-drain layer (see Fig 9). Well screened or perforated drainage pipe can be obtained for the bottom section of the drain pipe. Pump suction-lift extraction can be improved by using slotted collection drains placed horizontally in the 20mm bottom layer of stone, to direct the water to the extraction point. The majority of horticultural SSF installed in the UK have used this pump suction-lift approach to remove filtered water. It is important that the vertical suction lift capability of the chosen pump is not exceeded. Check with the supplier the maximum height through which suction lift can be achieved.

Alternatively, installation of a simple valved exit from the under-drain system works equally well and is very easy to construct, especially on a small scale - a good example of this is the HDC pilot filter tested in HDC project HNS 88a (Fig 12). The main potential drawback to a simple under-drain system is an increased chance of leaks resulting from the placement of a valved outlet low on the side of the filter unit.

The rate of flow of water through the filter is controlled either by an exit valve on an under-drain system, or by the flow rate of the pump in a lifting system.

Basically, there is a great deal of flexibility in SSF design, so long as three basic principles are adhered to:

1. Ensure sand depth is never less than 0.5m.
2. Maintain a reasonably constant water flow rate through the sand between 0.1-0.3m/h.
3. Avoid breaks in the flow of water through the filter sand.

Basic components of a SSF system

Flow rates are often referred to as the depth of water passing through the filter per hour, eg 0.1-0.3m/h. The volume per hour in m^3 is then easily calculated by multiplying this figure by the surface area of the filter in m^2.

Fig 12

Small scale pilot sand filter showing flow rate control using a simple tap

Treated water storage facility

Since SSF are run continuously at a slow rate, it is inappropriate and inefficient to have their output fed directly into the irrigation system. It is best to feed the treated water into a clean storage tank/reservoir. Generally the costs and available space are most likely to be the limiting factors deciding storage capacity on a UK nursery, and in most cases it is probably best to aim for the largest storage capacity economically possible.

The clean water storage tank needs to have a capacity capable of holding at least 2-3 and preferably 5-6 times the 24h production capacity of the SSF (the minimum size advisable would be sufficient for 1 full day's watering at maximum rate plus a 10% safety margin). This gives buffering for possible filter down-time for maintenance and also provides some space for excess clean water during periods of lower demand.

What happens when the storage facilities are full?

Once the clean water storage tank/reservoir is full, the SSF can be either run to waste, run back to the collection reservoir or run in 'recycle mode' by feeding the filtered water back into the head of water above the sand (see Fig 10). The latter choice often results in a rapid and dramatic impact, cleaning up the algae etc. In addition to these measures, it is also possible to reduce the filter flow rate as in winter-time.

Fig 13

Recirculation process in operation

Layout & installation

When thinking about installing a SSF system, there are a number of considerations to bear in mind. Many of these, including the handling of raw water, pre-filtration treatments and the storage of treated water, are relevant to any type of water recycling system. However, some points are specific to SSF.

The important considerations on the layout and installation of a complete system developing SSF can be summarised as follows:

1. Raw Water

- Determine your future water requirements especially allowing for any planned expansion.
- Identify water sources available, costs of water from each source and whether they need on-site treatment.
- Estimate volumes collectable from roofs and/or beds using local rainfall averages.
- If considering collection and recycling of bed runoff, weigh up costs and practicalities of restructuring.
- Identify suitable location(s) for storage reservoir(s) for collected raw water.
- Determine optimum raw water reservoir volume: a balance between cost savings, installation costs and the space available.

2. Pre-filtration

- Have the particulates load in raw water measured.
- Is pre-filtration necessary?
- Determine the type, size, cost and location of pre-filtration device.

3. SSF column

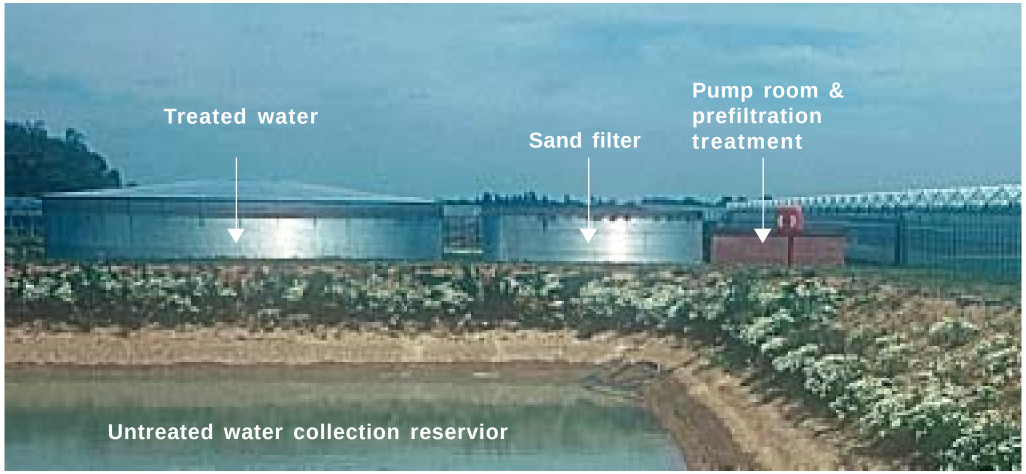
- Determine the ideal size of filter needed based on treated water requirements.

Typical irrigation water requirements of a nursery

Area of nursery m^2	Annual storage m^3	Clean water daily storage m^3	SSF area m^2	Suggested treated water tank diameter m
1,000	700	10	2.9	2.7
2,500	1,750	20	6.0	2.7
5,000	3,500	35	10.0	3.7
7,500	5,250	55	16.0	4.5
10,000	7,000	70	20.0	5.5

Fig 14

Classic SSF system setup, Roundstone Nurseries



Layout & installation

- Space considerations as well as raw and treated water storage capacities may restrict the feasible size of SSF required.
- Consider the location of the filter and how raw water will be transported to and treated water removed from the filter.
- Calculate equipment and installation costs for the filter.

4. Treated water storage

- Identify the best location for treated water storage.
- Decide whether to use a tank or reservoir for treated water storage.
- Determine the size of treated water facility required and available space.

As a general rule of thumb, one of the most important things to remember is that the size of both the treated and untreated water storage facilities should be a large as space and economics allow.

For more information on installation and capital costs, see section on Case Studies page 26.

Layout

It should be remembered that the SSF column must run continuously. The continuous slow flow is not really suitable for feeding straight into an irrigation system, hence a clean water storage tank or reservoir is essential with sufficient capacity for several days watering at maximum rate. Also, since the filter must never run dry, the source(s) of untreated water must be reliable. The ideal set-up consists of a large holding reservoir for untreated water feeding to a medium-sized treated-water storage tank via the SSF.

On a flat site, the positioning of the water storage and treatment facilities is really a matter of fitting in a convenient location in relation to the other structures. On a sloping site, the topography can sometimes be utilised to improve the efficiency of water collection, with untreated storage located at the lowest possible part of the site. SSF treatment plants and clean water storage can be located in a higher position. This separation of treated from untreated water storage will help to avoid contamination of the clean treated water.

Slow sand filter system requirements for a range of nursery sizes

Size of irrigation area m^2	Typical daily water requirement m^3 (*1)	Untreated water storage requirement p.a. m^3	SSF area required m^2	Treated water storage requirement m^3	Suggested tank diameter m
1,000	6.2	700	2.9	10	2.70(*2)
2,500	15.5	1,750	6.0	20	2.70
5,000	31.0	3,500	10.0	35	3.70
7,500	46.5	5,500	16.0	55	4.50
10,000	62.0	7,000	20.0	70	5.50

*1 Assumes up to 35% of water is recycled

*2 Smallest tank diameter available to achieve SSF surface area

Operation

Fig 15

Splash device in operation for aeration of filter water

What is priming?

Before a newly installed SSF can be used to remove plant pathogens from irrigation water it must be primed. Priming is the start-up period when the development of the natural biofilm on sand grain surfaces is encouraged. This biofilm contains bacteria that are vital in removing plant pathogens. To prime a new SSF, raw water is continuously passed through the filter and run to waste until a sufficiently active biofilm layer has built up.

The length of the priming period is variable, lasting from one, but rarely longer than 3 weeks. Taking samples of the raw and filtered water and getting assessments of the micro-organisms present in them gives a very good measure of when a filter is primed. During the filter priming period it is advisable to have water samples tested frequently (at least weekly - contact Tim Pettitt at the Eden Project on 01726 811920 or Martin McPherson at Stockbridge Technology Centre on 01757 268275).

Is there any substance I can add to hasten priming?

There are products marketed that are said to improve and speed up the priming process. However, the majority of those that have been tested at Warwick HRI had little impact on the natural biofilm build-up or its efficacy, and some materials (plant extracts) containing large amounts of organic matter even had a deleterious effect.

Does the water need to be kept aerated?

The oxygen-loving bacteria in the active biofilm layer obtain nutrition and dissolved oxygen from the water passing through the filter. To maintain healthy, active populations of bacteria, a high degree of oxygenation is desirable.

Splashing or spraying water onto the water surface of the filter is a good way of both introducing oxygen and keeping the water moving, helping to avoid ice formation which can seriously deplete oxygen entering the filter. Prolonged breaks in the water flow, especially in warm weather, can lead to the development of anoxic conditions and 'kill' the filter biofilm necessitating repriming. For this reason, the flow of water through the sand filter should be maintained all the time and kept reasonably constant.

What is the typical performance and throughput?

SSF operate effectively at flow rates between 0.1 and 0.25m/h, and if a good quality sand is used, up to 0.3m/h. Flow rates are often referred to as the depth of water passing through the filter per hour, eg 0.1-0.3m/h. The volume per hour in m^3 is then easily calculated by multiplying this figure by the surface area of the filter in m^2.

How often does a SSF unit need to be checked?

Ideally, a SSF should be quickly checked on a daily basis. This should be a visual inspection to make sure the pumps are running properly, that there are no leaks or unusual noises etc, and that the water levels are correct. In addition the flow meter should be checked and a record taken, and the pre-filtration device(s) checked. For example the frequency of back-flushes will give an indication of potential problems with the raw water quality.

How often should water quality be tested?

Electroconductivity and pH should be checked on a weekly basis. In addition, if the raw water is recovered from production beds, the mineral content of the treated water should be regularly analysed. See section on Suppliers and Consultants for contact details of companies that can test water.

Should I test for plant pathogens?

As with any water treatment system for removal of plant pathogens, analysis of SSF-treated water for the presence of plant pathogens should be carried out to check treatment efficacy. This should be done monthly or bi-monthly and whenever an operation such as cleaning has been carried out. Tests cost approximately £75 each plus VAT and include information on water quality.

What records should I keep?

It is worthwhile consolidating any records of water volumes treated, flow rates and pre-filtration back-flush frequencies once per week, as well kept records are a very powerful management tool for spotting and avoiding potential problems such as unwanted filter blockages. Keeping records will quickly help to establish confidence in the system itself and provide useful evidence for accreditation schemes (eg BOPP Ornamentals Accreditation Scheme) that the water source being used is being properly monitored and cleanliness substantiated.

Records of the results of electroconductivity, pH, mineral analyses and pathogen tests should be kept together with the flow records so that if problems arise, the two sources of information can be compared to help trouble-shooting.

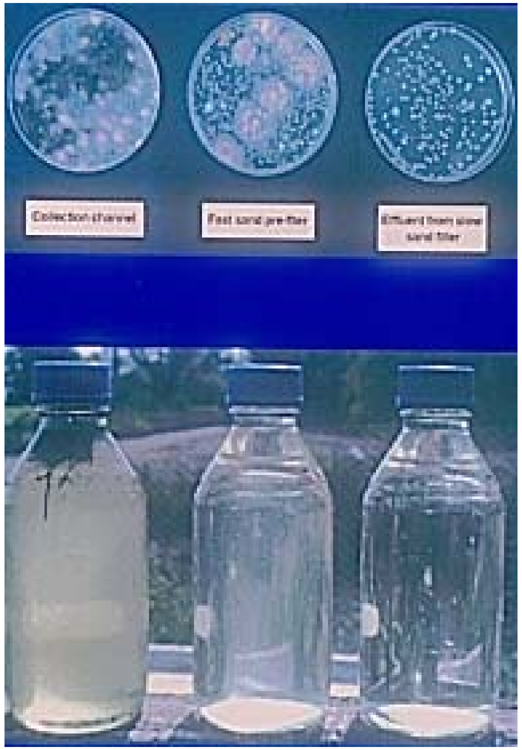
Does it matter if there are algal blooms in the collection pond?

Intense algal blooms can occur after periods when the SSF has been idle (eg over winter) and the collection pond has collected much nutrient-enriched run-off water. With sudden periods of high light (eg in early spring) rapid algal growth can occur and certain species, if not treated will quickly block the SSF.

A number of alternatives can be used to remedy this problem. If the pond is small enough, it can be covered to prevent light penetration. Barley straw, the decay of which releases natural algal inhibitors into the water with no apparent adverse environmental effects on other pond inhabitants, has been successfully used to control algal blooms. In addition, experience has shown that if the SSF is run continuously at a slow rate and the treated water returned to the collection pond over winter, algal blooms are less likely to be problematic.

Fig 16

Visual quality and pathology plates from dirty, pre-filtered and SSF water (left to right)



Maintenance

When do SSF need cleaning and how can you tell?

A SSF needs to be cleaned when a rapid decline is seen in the rate that treated water is produced. This is the result of fine particles collecting on and clogging the filter surface, increasing its resistance to the water flow. When the flow rate cannot be further regulated by adjusting the rate of pumping in a suction-lift pumping system or by gradually opening the delivery valve on a submersible pump in the under-drain system, the flow will rapidly decline and the sand surface will need to be cleaned. The frequency of this happening depends on the quality of the raw water and the pre-filtration treatment. A properly maintained SSF with good pre-filtration should not require cleaning more than once per season.

The timing of cleaning can also be determined by monitoring the increase in head-loss through the sand. Head-loss is the resistance to flow created by the filter.

Directly recording head-loss has the advantage that it can give advanced warning of possible problems, such as a failure in the pre-filtration system, before it becomes necessary to clean the filter.

When the head-loss exceeds 60% of the height of head above the filter sand cleaning would be advisable (H_3, Fig 20). It can easily be measured by placing a tube through the sand to the under-drain layer and measuring the height of the water column in this tube (H_2, Fig 20) using a simple float.

How is the filter cleaned?

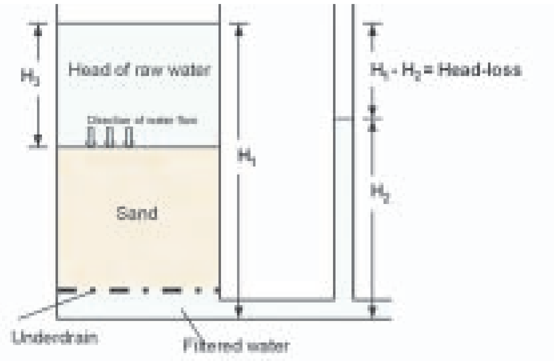
Filter cleanups are straightforward, but should be kept to an absolute minimum as they can be disruptive and add significantly to filter running costs by:

- Causing the filter to be out of operation for 1-2 days.
- High labour inputs required to scrape the clogged sand surface (approximately 30m^2 of filter surface can be scraped in 1 man-hour).
- Creating sand loss (the more frequent the cleanups, the more often sand will need to be replaced).

To carry out a filter cleanup, first the water is drained down to below the sand surface, the clogged surface layer of sand (approximately 1-3cm) is removed with a shovel. After levelling the scraped surface with a rake, the sand is recharged with clean water from below until the water level is about 5-10cm above the sand surface. This allows the sand surface to settle, prevents the raw water inlet from scouring the sand surface and reduces the formation of air pockets in the filter profile. Once the water depth above the sand is between 5-10cm, the raw water inlet can be switched back on and the SSF is run back to the raw water collection reservoir for 24h to reprime, after which it can be switched back into production.

Fig 17

Diagram of SSF system illustrating the derivation of head-loss



Maintenance

How often will a SSF require re-sanding and how is it done?

With a sand depth of 1m, a sand filter can be cleaned, by scraping, between 25 and 40 times before the minimum effective depth of sand is reached. At this stage more sand needs to be added; re-sanding. The frequency of these clean-ups and therefore the frequency of re-sanding, depends on the quality of the water being treated and the efficacy of the pre-filtration used. There are two methods of re-sanding:

Method 1

A deeper than usual scrape (5-10cm) is carried out and then replaced with new sand and is levelled bringing the sand depth back up to approximately 1m.

Method 2

The best (and unfortunately most labour intensive) method involves double digging the old sand and placing the new sand underneath so that the old sand forms the top layer and is therefore gradually removed from the filter in subsequent scrapings.

Method 2 is better because it avoids the build-up of deposits of fine particles of silt in the lower layers of the sand, which would ultimately increase the filter's resistance to the water flow and therefore its efficacy.

How is used sand disposed of?

The sand scrapings from a cleaned filter contain suspended organic matter and microbes extracted from the raw water concentrated in the dark coloured matter that has actually caused the filter blockage. Some of these could be harmful and whilst the risks are small, this sand should be treated with caution (about the same level as one would treat partially rotted compost). Used sand is best placed on the ground such that the water can drain from it and it is exposed to sunlight and weathering.

What should be done in winter?

Once the demand for water declines in winter, the SSF flow rate can be reduced to a level around 0.01m/h, this keeps the water in the system moving, preventing ice formation, and maintains a supply of oxygen and nutrition to the biofilm layer. Alternatively, the pumps may be switched off and the system drained-down to prevent ice damage to pipework. It is best not to let the sand completely dry out, but it is not good to leave still water over the sand for a long period of time (weeks in winter as opposed to days in summer). When the filter is to be used again it will need re-priming - this can happen very quickly (1-2 days), but it is best to allow 1-3 weeks for re-priming, remembering to get a laboratory water test for pathogens before irrigating with it.

What is the expected life-span of SSF equipment?

This depends on the equipment used to build the filter, but a minimum life span of 10-15 years would be expected for the butyl-lined steel tanks used for many horticultural SSF.

Can pesticide usage be reduced as a result of using SSF?

Once a track record of reliability has been established experience indicates that reliance on the use of fungicide drenches for treating root diseases can be significantly reduced.

Fig 18

Filter cleaning operation in progress

Fig 19

Comparison of filter sand before (left) and after (right) cleaning has taken place

Financial & environmental considerations

Fig 20

Raw water collection reservoir - build as large as space and capital allow

What are the financial incentives to encourage SSF installation?

- Costs of mains water ranges from 50p to £1.25/m^3 and is rising. On a typical nursery the use of SSF, in conjunction with water collection and recycling, can cut mains water usage by up to 50%.
- If space and available capital allow the construction of a large enough reservoir, collection of rainwater during winter and subsequent SSF treatment can often eliminate the need for mains water.
- Successful use of SSF will significantly reduce the need for root disease fungicides, giving potential savings of between 20 and 50p/m^2 of production bed area per annum.
- When SSF is used to treat predominantly rain-derived water, the treated water quality is high and therefore has a positive impact on production quality.

What future legislation will affect water use and encourage the need for SSF installation?

- Ground and surface water abstraction licence availability.
- Water Framework Directive and pollution.

What are the environmental incentives to encourage SSF installation?

- SSF is currently the most environmentally friendly method available for successfully treating water to remove plant pathogens.
- Recycling nursery water by using SSF as part of the water treatment system:
  - helps with water conservation by reducing need for mains or extracted (eg borehole or river) water.
  - can reduce the risks of flooding.
  - avoids the risk of pollution downstream - especially important in NVZs.
  - has a positive impact on wildlife - collection ponds and reservoirs attract wildlife and can be more stable in terms of water quality as a result. SSF is a wildlife-friendly method for treating this water.

What are the running costs?

- Labour: once a SSF is established, general operational labour is minimal. The major costs are for the following operations associated with filter cleaning, the frequency of which is determined by the quality of the water to be treated:
  - filter cleaning / scraping - varies with filter area eg to clean 30m^2 will take approx 3 man hours, whilst 140m^2 will take approx 8 man hours.
  - re-sanding the filter - varies greatly with water quality eg once every 10 years where water quality is high and as often as every 2 years with poor quality water. The labour required varies with filter size over the range 15-30 man hours.
- Downtime & cleaning costs: the frequency of cleaning and associated costs depends on the incoming water quality. In addition to the labour costs, the cost of cleaning operations needs to include the cost of lost water production, which can range from

approximately £10 (where borehole water is used) to £500 (where mains water is used).

- Costs of running equipment: the main cost here is that of running pumps, and this varies according to the volumes of water treated and the distances and heights the water is moved around the nursery between collection reservoirs, treatment and storage tanks. (Individual pump running costs vary but for a 4litre/second submersible pump running for 1 day @ 17h on daytime tariff and 7h on economy tariff, the cost is £1.40 per day).
- Sand costs: The rate at which sand needs to be replaced depends on the frequency of cleaning operations, which in turn depend upon the quality of the water and the pre-filtration. Sand costs vary from £10 to £30 per tonne and for a SSF of 6 meter diameter (capable of treating approx. 70-130m^3 water per day) approximately 50 tonnes of sand are required.

Are there any grants available to set up a SSF?

Growers who are considering investing in SSF as part of developing and improving the water management on their nurseries should acquaint themselves with the England Rural Development Programme (http://www.defra.gov.uk/erdp/default.htm). Under this programme, which commenced in 2000 and runs until 2006, there are two possible options where your project application may be considered for grant aid.

1) The Rural Enterprise Scheme
(http://www.defra.gov.uk/erdp/schemes/res/default.htm)

Potentially your improvements would be eligible under the category 'Agricultural Water Resources Management', which may attract a grant of 20-50% of costs, where an economic return to the applicant is the primary objective of the project.

Alternatively, where the proposed project is large (ie over £70,000), you may consider an application under the Processing and Marketing Grant.

2) Processing and Marketing Grants
(http://www.defra.gov.uk/erdp/schemes/pmg/default.htm)

To be eligible for a PMG a proposed project has to meet one or more of the scheme's objectives:

- Achieve the better use of or elimination of by-products or waste.
- Apply new technologies.
- Apply innovation.
- Protect the environment.

PMGs are awarded on a competitive basis (ie only the best applications receive grants within the available budget). Awards may be for up to 30% of eligible project costs.

Making an application

All improvements in water use, including deploying SSF, need to be considered carefully together with the contributions of these to the environment and wildlife welfare to ensure that the proposed project meets the overall aspirations of the England Rural Development Plan.

Fig 21

SSF cleaning in progress - downtime and cleaning costs must be taken into consideration

Case Studies

Case 1

Hewton Nursery

Why did Hewton's decide to install a SSF?

In the dry summers of 1994/5 the nursery management team had concerns that if their mains water supply failed, they had no alternative water source to use. In addition Nigel Timpson, the Managing Director was anxious to opt for a more environmentally sustainable irrigation method. At that time Hewton's were contemplating the construction of a new glasshouse propagation block. They designed the new block to collect the roof water and store it in a new reservoir and Tim Pettitt designed a SSF using a local sand suitable for filtration.

Hewton Nursery produces 100% liners including trees, shrubs and perennials, climbers and ornamental grasses including bamboo grown under protection. The production area is a mixture of glass and polythene structures totalling 16,535m^2.

Fig 22

Hewton Nursery SSF setup

Benefits and returns

- 50% substitution of the mains water supply, saving £4,200 per year.
- Back-up supply of water in the event of mains breakdown / or drought.
- More environmentally sound method of waste water and rainfall use.
- Using SSF treated water has meant a reduced reliance on pesticides to control root pathogens, saving £3,500 per year.

What would Hewton's Nursery team have done differently?

- Made the decision to build a SSF sooner.
- Plan for extra storage capacity of clean water.
- Plan the site to use natural land levels to locate reservoirs and then use syphon techniques (reducing the need to pump water).
- From the beginning, pump at night to take advantage of the lower electricity tariff.

Case 2
Roundstone Nurseries, Newlands site

Why did Roundstone Nurseries decide to install a SSF?

The Newlands nursery site produces a wide range of seed raised pack bedding in 7.3 hectares of glass. When the new nursery was built it was decided to maximise the use of rainwater collected from the greenhouse roofs. This was for a number of reasons. The quality of rainwater is far superior to the local mains water having a lower alkalinity and EC. Whilst the cost savings over using mains are not that great, using rainwater is environmentally friendly, reduces reliance on mains water (which is often in short supply) and significantly reduces flood risks on both the nursery and its immediate locality.

SSF was used to eliminate the risks of pathogens contaminating the roof water. It was the preferred option as it is more effective than UV and chlorination carries too many risks with phytotoxicity.

The untreated water collection reservoir was built to the maximum size possible within the restrictions of the site, but if it were possible, Roundstone Nurseries would liked to have built an even larger reservoir. Nevertheless, the current reservoir allows the collection of sufficient rainwater over the year for the nursery's current irrigation requirements.

The nursery does not recycle used irrigation water as there is very little waste water. Irrigation is carried out by a very efficient 'state of the art' gantry watering system and Roundstone Nurseries also have long maintained a policy for economical use of water.

Benefits and returns

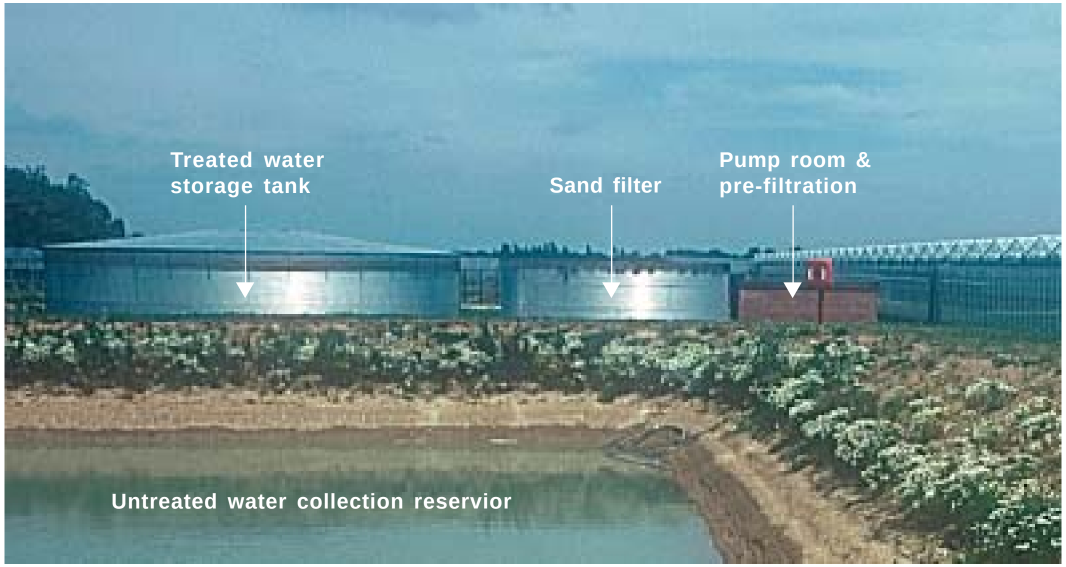
- 100% substitution of mains and borehole water.
- Large improvement of irrigation water quality.
- More environmentally sound method of waste water and rainfall use.

What would Roundstone Nurseries' team have done differently?

- If space had permitted, they would have built a larger reservoir for untreated water.

Fig 23

Classic SSF system setup, Roundstone Nurseries



Case 3
Notcutts Nurseries, Melton site

Why did Notcutts decide to install a SSF?

In the dry summers of 1994/5 the nursery management teams at Notcutts had concerns that the borehole was not adequate enough. They also wanted to collect the run-off from the growing beds and re-cycle it safely and confidently back to growing crops. It was important for the plants and peace of mind for the management that disease was not likely to be recycled too.

Notcutts Melton Nursery produces woody ornamental plants grown under protection and on outdoor beds on production area of 8.0ha.

Fig 24

Covered SSF at Notcutts Melton site

(Run off water is collected via the sealed concrete gulley ways which also serve as tractor access tracks. The gulley's inter-connect and allow the water to flow of downhill to the collection point located at the lowest point on the nursery.)

Benefits and returns

Back up supply of water in the event of mains breakdown / or drought as for Hewton's Nursery but also:

- 25% substitution of the borehole water supply.

What would Notcutts Nursery team have done differently?

- Planned for extra capacity for storage of clean processed water.
- Fitted a rain sensor switch to the submersible pump in the collecting reservoir.
- Constructed the storage tanks on higher level to enable siphon techniques to be used in the event of electricity failure.
- Used a low night rate tariff from the beginning to move water to storage.

Small Scale Filter

One of the attractions of SSF is its flexibility and the possibility to use it on a more modest scale than illustrated in the three fully commercial case studies already mentioned.

At the former HRI Efford a smaller SSF unit was constructed and operated in realistic scale experiments to produce 30m^3 of treated water per day. This system was constructed from a 2.74m diameter butyl-lined galvanised steel tank. Raw water was stored in a 150m^3 butyl-lined dug reservoir, and was pumped to the filter via a 'Cross Easy Clean' pre-filter (see HDC report HNS 88b) using a float-switch operated borehole pump. Treated water was lifted from the filter by a second pump to a 60m^3 butyl-lined galvanised steel storage tank.

As this system was run for experimental purposes, costings can only be provided for the equipment described and not for the arrangement of nursery beds or potential commercial cost savings. However, the following information will hopefully be helpful to smaller nurseries when trying to make cost estimates for smaller-scale water treatment.

The costs for the Efford system can be broken down as follows:

- Raw water storage pond £2500
- Slow Sand Filter £1000
- Pre-filtration unit £1000
- Storage tank £2000
- Pumps and fittings £800.

Fig 25

Awaiting caption from Tim ???

Case Studies - at a glance

Item	Hewton Nursery	Roundstone Nurseries	Notcutts Nursery
SSF construction			
Type of SSF	Galvanised corrugated steel tank with cover	Galvanised corrugated steel tank with cover	Soil excavation, bunded with butly liner, roof of black polythene
Size of SSF (surface area m²)	31.2	80	126.0
Pre-filtration method	Graded sand filter with backwash facility (Odis)	Reservoir settlement (roof-water only)	Pond settlement
Water storage - treated and untreated			
Untreated water storage capacity (m³)	500	6,500	516
Treated water storage capacity (m³)	304	500	600
Operation			
Output per day (m³)	74	288	345
Routine pathological tests per year (at £75 each + VAT)	10	5	5
Maintenance	Cleaning twice per year, 2 man hours each time In the last 4 years there has not been a need to replenish the sand	Cleaning once every 2 years, 4 man hours each time There has not been a need to replenish the sand to date	Cleaning once per month, 4 man hours each time Recharging sand every 2 years £500 plus labour
Water requirement			
Total water use per year (m³)	12,000	13,500 (estimate)	112,000
Water collected per year (m³)	6,000 (from roof water)	12,000	16,250 (from production beds and rain water)
Area water collected from (m²)	10,700	70,000	80,000
Mains/borehole water use per year (m³)	6,000 (mains)	1,500 (mains for offices)	96,250 (borehole)
% of total water used recycled each year	50	95	25

Case Studies - at a glance

Item	Hewton Nursery	Roundstone Nurseries	Notcutts Nursery
Water costs			
Cost of treating 1000 m³ of water (collecting, storing, filtration, pumping) (£)	195	178	141
Costs of borehole water per 1000 m³ (£)	N/A	N/A	133
Cost of mains water per 1000 m³ (£)	788	600	850
Cost savings over mains water per year per 1000 m³ (£)	543	422	709
Payback on investment			
SSF (£)	7,000	20,000	20,000
Reservoir (£)	18,000	60,000	5,000
Storage of treated water (£)	7,808	6,000	5,000
Nursery capital costs (£)	32,808	86,000	30,000
Finance costs (£)	16,076	42,140	14,700
Total cost	*48,884*	*128,140*	*44,700*
Savings per 1000 m³ (£)	643	422	209
Volume utilised (1000 m³)	6.0	12.8	28.0
Annual saving (£)	3,858	5,402	5,852
Payback period			
Capital spend with no financial appraisal (years)	8.5	15.9	5.13
Capital spend with financial appraisal (years)	12.60	23.72	7.64

Suppliers & consultants with experience and knowledge of SSF

Organisation	Contact	Specialism	Contact details
c/o Eden Project	Tim Pettitt	Consultancy, design, water testing pre-filtration	tpettitt@edenproject.com tel. 01726 811900
Cross Manufacturing	Tom Cross	Pre-filtration	tom@crossmanufacturing.com tel. 01225 837000
ADAS	David Hutchinson	Consultancy, design, sampling	David.Hutchinson@adas.co.uk tel. 023 80251191
Evenproducts		Equipment or design and full build	sales@evenproducts.com tel. 01386 760950
Flowering plants		Equipment, design and consultancy	Richardson@floweringplants-freeserve.co.uk tel. 01280 813764
Hortisystems UK		Equipment or design and full build	sales@hortisystems.co.uk tel. 01798 815815
LVZ Automation		Design and full build	info@lvz-automation.co.uk tel. 01243 860700
Revaho UK		Equipment - pumps, pipework and pre-filtration	stewart@recaho.co.uk tel. 01695 556222
STC	Martin McPherson	Water testing	martinmcpherson@stc-nyorks.co.uk tel. 01757 268275

Whilst every effort has been made to ensure that these details are as accurate and comprehensive as possible, the Horticultural Development Council accepts no liability for errors or omissions.

Inclusion in or exclusion from this list does not infer approval or otherwise of any company or organisation.

Further help & information

Sources of information

HDC Reports

'Monitoring the commercial development of slow sand filtration'
HDC project HNS 88

'Development of a low cost test procedure for assessing the efficacy of slow sand filtration on individual nurseries'
HDC project HNS 88a

'Slow sand filtration in HNS production: assessment of pre-filtration treatments of water to reduce the frequency of filter cleaning operations'
HDC project HNS 88b

Technical notes, guides and other publications

'Managing Water in Plant Nurseries. A Guide to Irrigation, Drainage and Water Recycling in Containerised Plant Nurseries'
1994 Horticultural Research and Development Corporation, Nursery Industry Association of Australia and NSW Agriculture ISBN 0 7310 3214 4

Slow Sand Filtration for Community Water Supply - planning, design, construction, operation and maintenance
No 24 Technical Paper series
IRC - International Reference Centre for Community Water Supply and Sanitation June 1987 ISBN 90-6687-009-5

Slow Sand Filtration - A report prepared by the Task Committee on Slow Sand Filtration
Edited by Gary S Logsdon
Published by the American Society of Civil Engineers, 345 East 47th Street New York 10017-2398
ISBN 0-6726 -8477

Legislation guides and codes of practice

'Code of Good Agricultural Practice for the Protection of Water' (The Water Code)
1998 Defra Publications

'Taking Water Responsibly - Government decisions following consultation on changes to the water abstraction licensing system in England and Wales'
1999 Defra Publications

'Tuning Water Taking - Government decisions following consultation on the use of economic instruments in relation to water abstraction'
2001 Defra Publications

Winter Storage Reservoirs - getting control over your water resource
Defra Publications

'Groundwater Regulations'
1999 Environment Agency

'The Water Supply (Water Fittings) Regulations 1999 and The Water Byelaws 2000 (Scotland) - What are they and how do they affect you?'
2001 The Water Regulations Advisory Scheme

'Water Supply Systems: Prevention of Contamination and Waste of Drinking Water Supplies - Agricultural Premises'
2001 The Water Regulations Advisory Scheme

'Guidelines for Farmers in NVZs - Nitrate Vulnerable Zones'
1998 Defra Publications

'How should England implement the 1991 Nitrates Directive?'

Further help and information

Relevant Organisations and Contact Details

Defra Publications
tel. 08459 556 000
www.defra.gov.uk

Environment Agency
tel. 08459 333 111
www.environment-agency.gov.uk
www.environment-agency.wales.gov.uk

ADAS
tel. 01954 268206
www.adas.co.uk/horticulture
www.horticulture-interactive.co.uk

The Water Regulations Advisory Scheme (WRAS)
tel. 01495 248454
www.wras.co.uk

Water UK, 1
tel 020 7344 1844
www.water.org.uk

Office of Water Services
tel. 0121 625 1300
www.ofwatgov.uk

Horticultural Development Council
tel. 01732 848383
www.hdc.org.uk

Horticultural
Development
Council

Bradbourne House
East Malling
Kent ME19 6DZ
T: 01732 848383
F: 01732 848498
E: hdc@hdc.org.uk
W: www.hdc.org.uk