Slow sand filtration

A small-scale slow sand filter is a tank, usually uncovered, containing a set of underdrains covered with graded gravel which supports a bed of fine sand. The tank is filled with water to above the level of the sand. The water passes down slowly through the sand to the underdrains and is purified as suspended particles and microbes are removed in the sand. Figure 1 shows a simple slow sand filter.

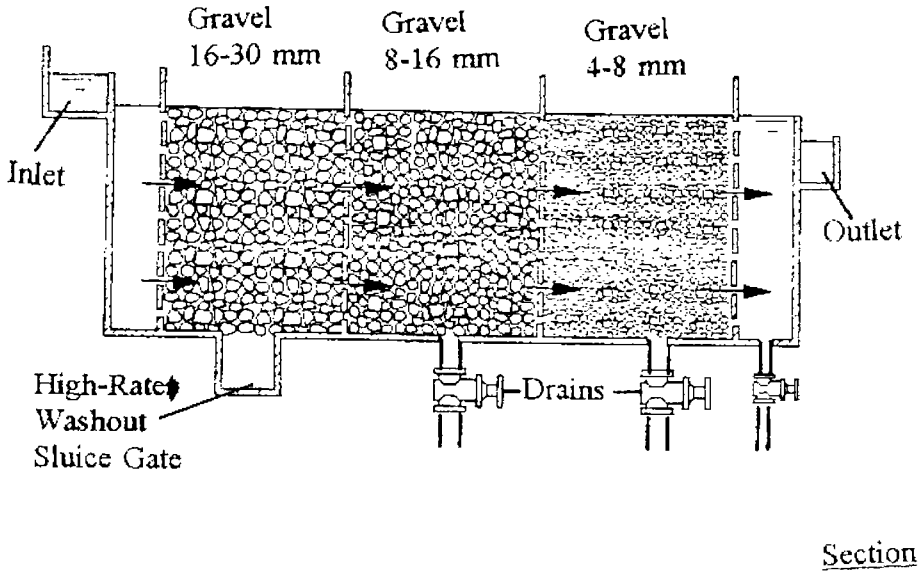

Figure 1. A simple slow sand filter

Incoming water must be relatively clear, with turbidity below a maximum 20 TU and ideally an average reading of below 10 TU.

After several weeks or months the top 0.5-2 cm of the sand becomes clogged and reduces the rate at which water can flow through the sand. When this happens, this top layer should be removed to restore the filtration capacity. Water should be allowed to flow through the filter for one or two days before the filter is put back into operation.

Flow control is essential and can be done at the inlet or outlet. A minimum head mechanism to prevent drying of the bed if the source of water is interrupted is essential, particularly where the source flow is variable.

Although slow sand filters are most commonly used for community water supplies, they can be built to serve individual households. These units generally work on a variable flow rate and because of this are likely to be much less efficient.

Sanitary inspections of slow sand filters

Sanitary inspections of slow sand filters should be carried out regularly to ensure that they are functioning correctly and that an adequate water supply is maintained (see Fact Sheet 2.1). The key points and observations to make during a sanitary inspection of a slow sand filter are :

- The turbidity of the inlet water should be below 10 TU.
- The turbidity of the outlet water should be below 5 TU.
- The flow rate in the filter should be constant and in the range 0.1 to 0.3 metres per hour.
- The depth of sand in the filter bed should be at least 0.7 metres.
- The filter should have a minimum head device which is in working order and in operation.
- The tank should have no leaks which would allow filter water to escape and surface water to enter.
- Sand removed during cleaning should be washed and restored.

Records of all the above and cleaning records should be checked.

Advantages and disadvantages of slow sand filters

Slow sand filters have the following advantages :

- Very effective in improving the microbiological and physicochemical qualities of water.
- Very easy to operate and maintain.

Disadvantages of slow sand filters are :

- Vulnerability to clogging when the incoming water is of high turbidity ; when dealing with such waters, pre-treatment, such as sedimentation or roughing pre-filtration, is required.
- Large areas of land are required on which to build the filter.

Factors influencing slow sand filtration efficiency

The removal of microbes and organics in a slow sand filter is a biological process. The efficiency of the filter is therefore affected by time, oxygen, temperature and the need for beneficial microbes in the water to grow. These are described below :

Time

The time available for the reactions to take place in the filter bed is determined by the sand depth and the flow rate ; these are discussed in more detail below, under " Slow sand filter installations ".

Oxygen

The activity of the bacteria in the filter bed uses up oxygen. If the amount of oxygen in the incoming water is low or it has a high organic content, the microbial reactions will be less effective and the bacterial quality of the outlet water will decrease.

Temperature

This is difficult to control, although filters can be covered in cold weather.

Maturation

The microorganisms in the filter which remove bacteria from the water take time to establish themselves. Slow sand filtration therefore operates less efficiently when it is first commissioned and after cleaning. Thus as long as possible should be left between each cleaning of the filter. Keeping the raw water turbidity as low as possible, by pre-treatment if necessary, is therefore important.

Slow sand filter installations

From experience gained in building slow sand filters, some general guidelines for filter design have been established as follows :

Population to be served

Slow sand filtration is more cost effective than rapid sand filtration for populations up to 30,000

and possibly considerably higher.

Raw water quality requirements

Incoming, or influent, water should not be too turbid, not exceeding 20 TU and ideally below 10 TU.

The most important raw water characteristic, however, is that the intake must be continuous and constant. Pumped systems will require storage facilities to ensure a constant supply rate.

The filter bed must not be allowed to dry out as this will kill the microorganisms which remove bacteria in water and cause a loss of purification efficiency.

Pretreatment

Where high peaks or high mean turbidities are present in the water, some form of pretreatment is required. This can take the form of gravel pre-filtration, sedimentation or primary storage, all of which remove suspended solids from water. Gravel pre-filtration is particularly applicable to small community water supplies, with horizontal and vertical upflow filtration being the most common.

Inlet structure

This should be designed to allow the water to enter the filter without disturbing the bed. This is usually done by using a plinth at the level of the sand to disperse the force of the falling water. To assist in the cleaning, all of the inlet, overflow or outlet structures should be designed to allow rapid drain-down before cleaning.

Filter bed

The depth of the bed affects the time available for treatment and so its efficiency. A minimum depth of 70 centimetres is required for the proper functioning of the filter bed. As about 2 centimetres will be removed during each cleaning, it is a good idea to add extra sand initially. The initial sand depth should therefore be at least 1 metre.

A minimum of two filter beds should be included in any slow sand filtration installation supplying a community water supply to ensure that water can be passed through one filter whilst the other is being cleaned.

Supernatant

This is the incoming water which lies on top of the sand to provide an adequate head of water over the filter.

Where flow control is practised at the inlet, clogging will cause the supernatant to rise. An overflow is required to take off excess water about 1 metre above the sand bed and once this level is reached the filter should be cleaned.

Filter medium

Sand is the most commonly used medium, although other granular materials, such as burnt rice or a mixture of charcoal, sand and gravel, have been used.

The most important characteristic of the filter medium is the diameter of sand grains and their uniformity or size range. The sand must have a low silt content ; river sand is preferred as it has less soluble salts in it. The filter medium should be of uniform grain size to make sure that the pores, or holes, between grains are the same size so that the filter's efficiency should be equal over the bed.

Underdrains

These ensure that filtration is uniform and takes place over the full bed. Underdrains are usually composed of perforated pipes, such as plastic drainage pipes, or a false floor. Examples of underdrains are shown in Figure 2. In all cases, the underdrains are covered by a layer of gravel.

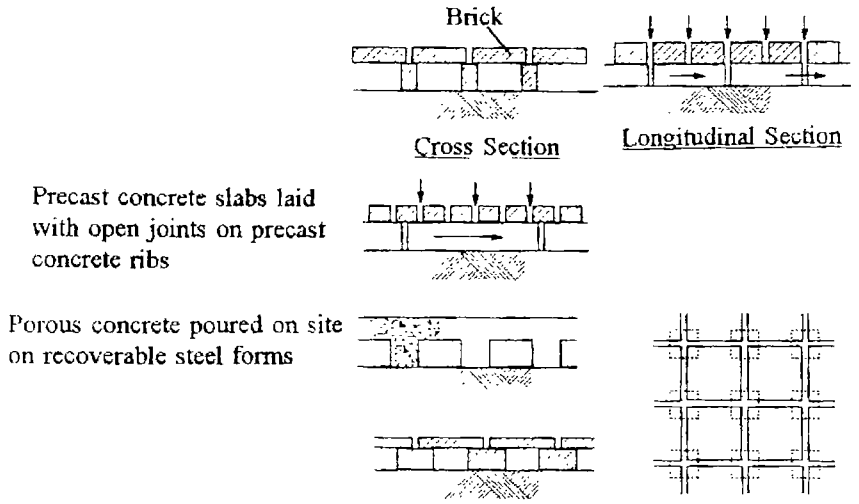

Figure 2. Examples of underdrains[1]

Outlet structure

This is used to prevent water being siphoned off and can also be used to re-aerate water if a weir is installed.

If a weir is used, it should be positioned above the level of the sand bed to prevent the sand drying out if the inflow is interrupted for any reason. The outlet should also allow back-filling through the underdrains with clean water after commissioning or re-sanding.

Flow rate

Flow rates vary, but should be between 0.1 and 0.3 metres per hour.

Flow control

Maintenance of a constant flow through the bed is important for filter efficiency. Flow control can be practised at the inlet or the outlet.

When the flow is controlled at the outlet, an outlet valve must be adjusted frequently, often daily, or output will fall. This ensures the maximum retention of water even at the beginning of a filter run. This method maximizes treatment efficiency but increases operator involvement.

Inlet flow control is often by gate valve plus a V-notch weir. As the resistance of the filter bed increases, the water level rises. When it reaches the overflow pipe the bed should be cleaned. Inlet flow control requires less operator involvement but decreases filter efficiency slightly.

[1] *Hofkes, E.H. (ed),* Small community water supplies, *International Water and Sanitation Centre, and John Wiley and Sons, The Hague, 1981*

Maintenance

Slow sand filters are very easy to maintain. Once the bed becomes clogged the top layer of sand is removed, as shown in Figure 3. To do this, the water in the bed is drained to 30-40 cm below the top of the bed and the top layer scraped off.

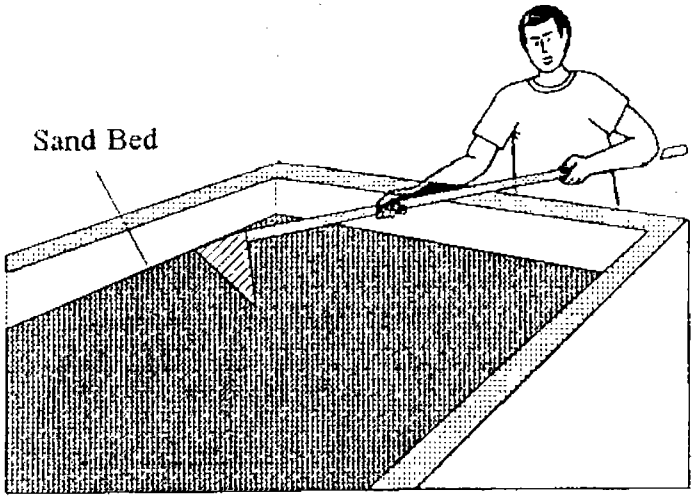

Figure 3. Filter cleaning

When this has been done, filtered water is allowed back through the system from the underdrains up to cover the sand layer. As this water flows through the bed, raw water may be re-introduced. It will, however, take 1-2 days before the bed is functioning properly. It may therefore be a good idea to re-filter the first raw water filtered after cleaning. The sand which was removed should be washed immediately (see Figure 4) to prevent it putrefying and then stored for re-use.

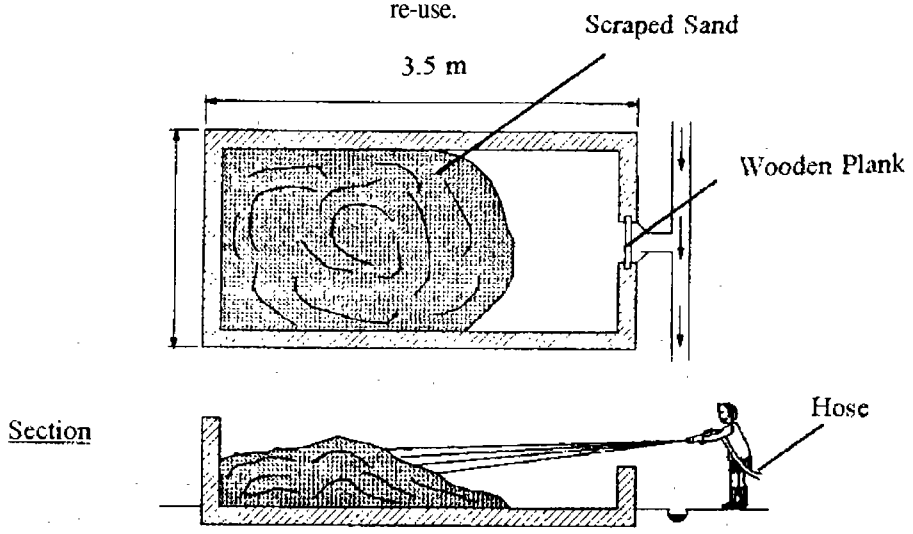

Figure 4. Sand washing

When the depth of sand in the bed has reached the minimum level of 0.7 metres, the bed must be re-sanded. An additional 0.3 metres of sand should be removed before the fresh sand is placed on the bed. Once the new sand is installed, this old sand can be replaced on top to promote the growth of bacteria.

An example of the schedule of activities for a slow sand filter caretaker is presented in the table below.

Slow sand filter maintenance tasks

Daily

- Check the raw water intake (some intakes may be checked less frequently)
- Check and adjust the rate of filtration
- Check water level in the filter
- Check water level in the clear water well
- Sample and check water quality
- Check any pumps
- Enter observations in the logbook of the plant

Weekly

- Check and grease any pumps and moving parts
- Check the stock of fuel ; order more if necessary
- Check the distribution network and taps ; repair if necessary
- Communicate with users
- Clean the site of the plant

Monthly

- Scrape the filter beds
- Wash the scrapings ; store the retained sand

Yearly

- Clean the clear water well
- Check that filter and clear water well are watertight

Every two years

- Re-sand the filter units