

59. Household water treatment 2

This Technical Brief is the second of two which examine the treatment of water at household level. The first (No.58) introduced the topic and covered treatment by straining, storage, settlement, solar disinfection, chemical disinfection and boiling. This Brief considers treatment by coagulation, flocculation, filtration and solar distillation and covers aspects of the reduction of some chemical concentrations.

Coagulation and flocculation

If raw water contains a large amount of fine suspended solids, coagulation and flocculation can be used to remove much of this material. In coagulation, a substance (usually in a liquid form), is added to the water to change the behaviour of the suspended particles. It causes the particles, which previously tended to repel each other, to be attracted towards each other, or towards the added material.

Coagulation takes place during a rapid mixing/stirring process which immediately follows the addition of the coagulant.

The flocculation process, which follows coagulation, usually consists of slow, gentle stirring. During flocculation, as the particles come into contact with each other they cling together to form larger particles which can be removed afterwards by settlement (see TB 58) or filtration. A chemical which is often used is alum (aluminium sulphate). Natural coagulants include some types of clay (e.g. bentonite) and powdered seeds of the *Moringa olifera* tree. The best type of coagulant and the required dose will depend on the physical properties (particularly the alkalinity/acidity) of the raw water and the amount and type of suspended solids.

Filtration

A number of processes take place in filters, including mechanical straining; absorption of suspended matter and chemicals; and, particularly in slow sand filters, biochemical processes. Depending on the size, type and depth of filter media, and the flow rate and the physical properties of the raw water, filters can remove suspended solids, pathogens, and certain chemicals, tastes, and odours.

Straining, and settlement (both described in TB 58) are treatment methods which usefully precede filtration to reduce the amount of suspended solids which enter the filtration stage. This increases the period for which a filter can operate before it needs cleaning. Coagulation and flocculation are also useful treatments to precede settlement and improve still further the removal of solids before filtration. If an effective system of removing the flocculated particles from the filter is feasible, then coagulation and flocculation can also be used before coarse sand filtration. Larger pathogens (e.g. parasitic worm eggs) are more readily removed by filtration than smaller pathogens (e.g. viruses).

Sand filtration

Slow sand filtration

In slow sand filtration the water passes slowly (e.g. flow velocity of 0.1 to 0.2m/h – i.e. $\text{m}^3/\text{m}^2/\text{h}$) downwards, through a bed

of fine sand. For the filter to perform well there should be no sudden changes in the flow rate and the water should not be very turbid (cloudy with suspended solids), or the filter will quickly become blocked. Good slow sand filters can produce good quality drinking-water.

There are a number of processes which improve the water quality as it passes through the filter, but pathogens are mainly removed in the very top layer of the filter bed where a biological film (called the 'schmutzdecke') builds up. In a well-designed and well-operated filter this film strains out bacteria. Deeper in the sand bed bacteria that pass through the schmutzdecke are killed by other micro-organisms, or they become attached to particles of sand until they die.

The schmutzdecke takes time to become effective, so water needs to flow through a new filter for at least a week before the filter will work efficiently.

The raw water should contain a fair amount of oxygen to promote the useful biological activity both in the schmutzdecke and further down into the filter bed.

After a period of use, the material filtered out of the water blocks the surface of the sand and reduces the flow rate to an unacceptable level. When this happens the filter is drained to expose the sand, and the top 15 to 20mm of the bed is carefully removed. When the filter is restarted, it takes a few days before the schmutzdecke builds up again to provide good quality water so, during this period, the water should not be used for potable purposes.

When successive cleaning operations cause the depth of sand to reach the minimum acceptable value (conventionally 650mm thick (see TB 15)), additional clean sand needs to be added to the bed.

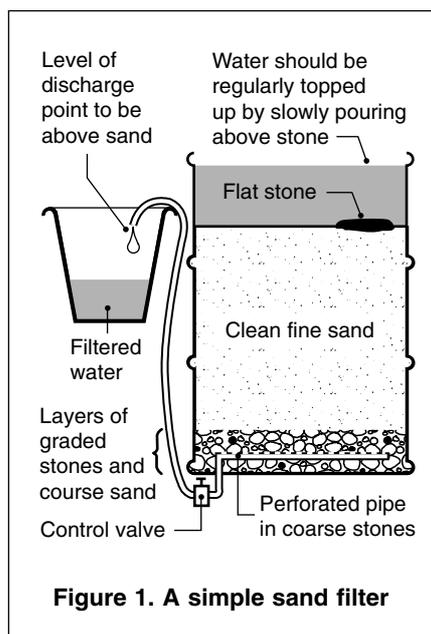


Figure 1. A simple sand filter

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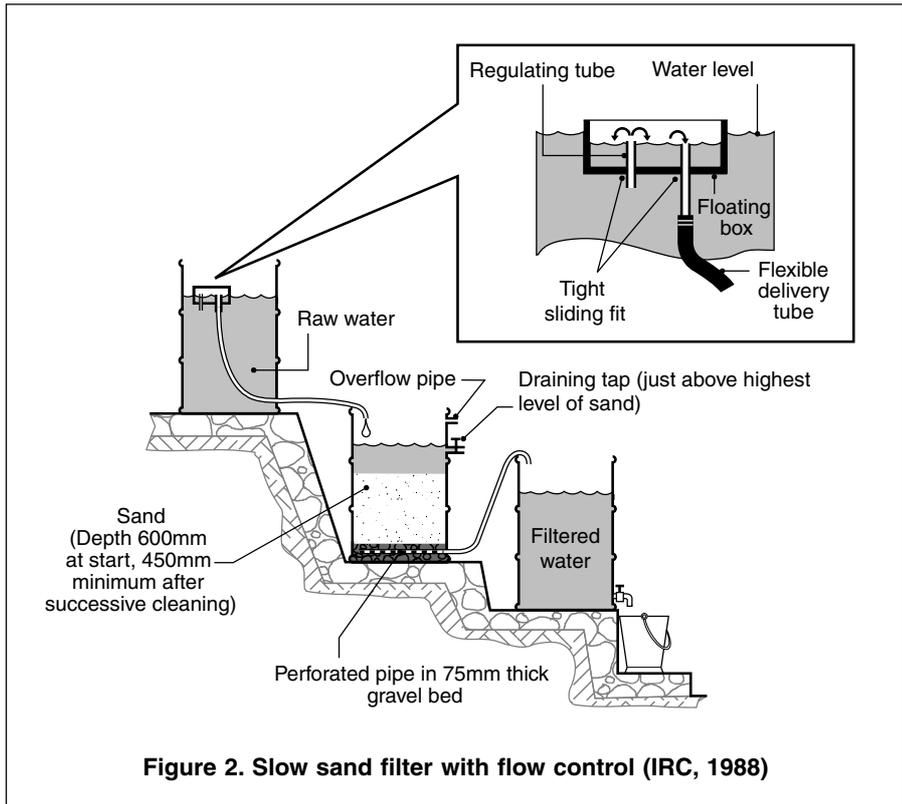


Figure 2. Slow sand filter with flow control (IRC, 1988)

When a slow sand filter is first started, water should be added from below so that it rises through the sand, pushing out the air. If water is added at the top, some air is likely to become trapped between the sand particles, adversely affecting the subsequent performance of the filter.

Many designs of household sand filters, such as that shown on the page 105, do not satisfy the recommendations for minimum depth of sand and for stable flow rate and, consequently their ability to remove all pathogens is suspect. A better, but more complicated, design of filter which uses a constant flow device is shown in Figure 2. Tests should always be carried out to check the effectiveness of any chosen filter design *before* it is promoted.

Rapid sand filtration

In this method the sand used is coarser than for slow sand filtration and the rate of flow is faster (conventionally the velocity of flow is between 4 and 8m/hr). Rapid sand filtration is used for removing suspended solids from water and is particularly effective after coagulation and flocculation. No schmutzdecke develops on these filters, so they are not effective at removing pathogens; the filtered water should subsequently be disinfected or passed through slow sand filters. There are two

main types of rapid sand filter; downflow and upflow.

In a *downflow* filter the water flows down through a layer of sand, ideally between 1 and 2m deep, below a depth of water of between 1.5 and 2.5m (although these depths are rarely practical for household filters which usually have shallower depths and are therefore less effective). When this type of filter becomes clogged, the flow is reversed to mobilize the sand particles and wash out the trapped solids. The operation of this type of filter is normally too complex for household use.

In *upflow* rapid sand filters the water passes up through the sand. To clean out debris trapped in the sand, the flow is made to reverse suddenly by opening a fast-acting valve below the filter bed. To prevent the build up of deposits in the sand, backwashing may be carried out every day, although if sufficient water and pressure is available for backwashing, a longer period will be acceptable. This type of filter is sometimes used at household level with shallower depths of sand and slower flow rates than for the conventional downflow filter mentioned above. The filter illustrated in Figure 3 is one shown by Heber (1985). It uses a 300mm depth of sand and a filtration rate of 0.5 to 1.5 m/h.

Childers and Claasen (1987) and Singh and Chaudhuri (1993) give details of the Unicef upward-flow water filter which works on a slightly different principle to conventional rapid upflow filters. The Unicef filter has three beds of media, a lower bed of fine sand followed by a bed of charcoal which is covered by a bed of coarse sand. It makes use of microbial action to reduce the number of pathogens, and regular backwashing is discouraged. It is capable of treating up to 40 l/day but is not effective at removing all pathogens.

Charcoal filters

As in the case of the UNICEF filter, granular charcoal can be used during filtration. It can be quite effective at removing some tastes, odours and colour. However, there is evidence that sometimes charcoal, particularly if not regularly replaced, can become the breeding ground for some harmful bacteria.

Some disadvantages of sand filters:

- good household sand filters are not cheap to construct;
- owners of such filters need to be well motivated to operate and carefully clean the filters correctly, and periodically to carry out the time-consuming task of renewing the sand bed. If any of these tasks are not carried out properly, the quality of the water will be unreliable;
- many of the cheaper household sand-filter designs are not able to produce pathogen-free water;
- an alternative source of potable water, or sufficient stored, treated water, needs to be available during the days immediately after the cleaning or re-sanding of slow sand filters.

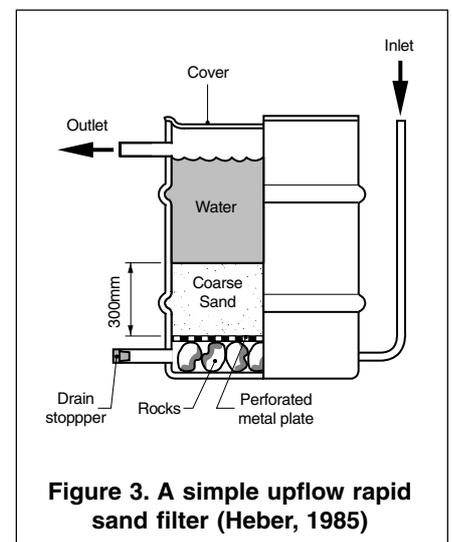


Figure 3. A simple upflow rapid sand filter (Heber, 1985)

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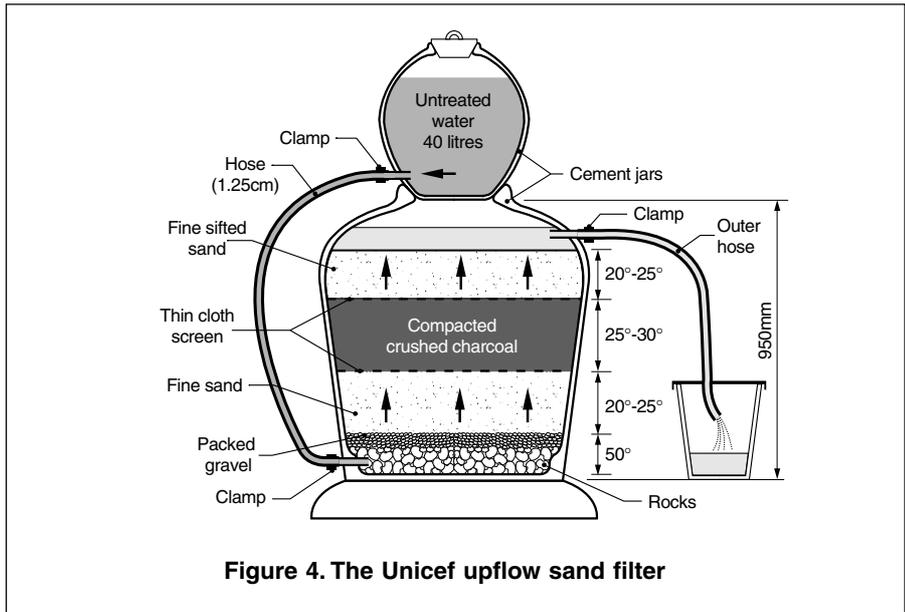


Figure 4. The Unicef upflow sand filter

Iron removal

High iron content (above 0.3mg/litre), is sometimes found in groundwater collected from boreholes. It can also be a result of the corrosion of steel (e.g. pipes, borehole casings and screens) from the action of acidic groundwater. Iron precipitates cause water discoloration and can impart an unpleasant metallic taste and odour to water as well as causing the staining of food and laundry. Iron is not known to have any detrimental effects on human health, but may cause an otherwise good quality groundwater source to be rejected in favour of a bacteriologically infected surface water source. The presence of organic compounds in the water significantly increase the concentration of iron held in solution. The metabolism of some bacteria is reliant on iron and they produce a red-brown slime; decay of these bacteria also produces unpleasant odours. Treatment methods are relatively simple, being based principally on aeration followed by filtration. Many different designs of small, simple, community-level iron-removal plants have been used with handpumps, but they need commitment from someone to carry out the periodic cleaning of the stones and sand which are used for absorption and filtration. Some removal methods use biological processes (Tyrrel et al. 1988). There is little information published about household iron-removal plants. However, aeration followed by settlement, and preferably also sand filtration, is usually effective at removing excess iron.

Manganese removal

Excessive manganese (above 0.1 mg/l) causes similar staining problems to excessive iron. Some forms of manganese can be removed by aeration followed by settlement or filtration.

Ceramic filters

The purifying element in these filters is a porous, unglazed, ceramic cylinder (often called a candle) which can be locally produced (Heber, 1985), but is usually mass-produced in factories. Manufactured filter units like that illustrated in Figure 5 (a) are available but are costly. If filter candles are available they can be fitted to earthenware pots (b); an alternative arrangement, which avoids the need for watertight connections through the jars, is to use a siphon pipe (c); open porous-clay jars (d) can also be used. Ceramic filters are appropriate only for fairly clear water because they block quickly if the water contains suspended particles. Their effectiveness depends on the size of the pores in the clay. Filters with very small pore sizes can remove all pathogens. The impurities are deposited on the surface of the candle, so need to be regularly scrubbed off to maintain a good flow rate. Boiling the filter after it has been cleaned

is also recommended to kill off the pathogens trapped in the pores, but some filters are impregnated with silver to kill micro-organisms. The scrubbing wears down the ceramic material, so periodically the candle needs to be replaced before it becomes too thin to guarantee the removal of all pathogens.

Reducing concentration of chemicals in water

Desalination

Excessive chemical salts in water make it unpalatable. Desalination by distillation (TB 40) produces water without chemical salts and various methods can be used at household level, for example to treat sea water. Desalination is also effective in removing other chemicals like fluoride, arsenic and iron. The water produced is relatively tasteless unless a little salt is added.

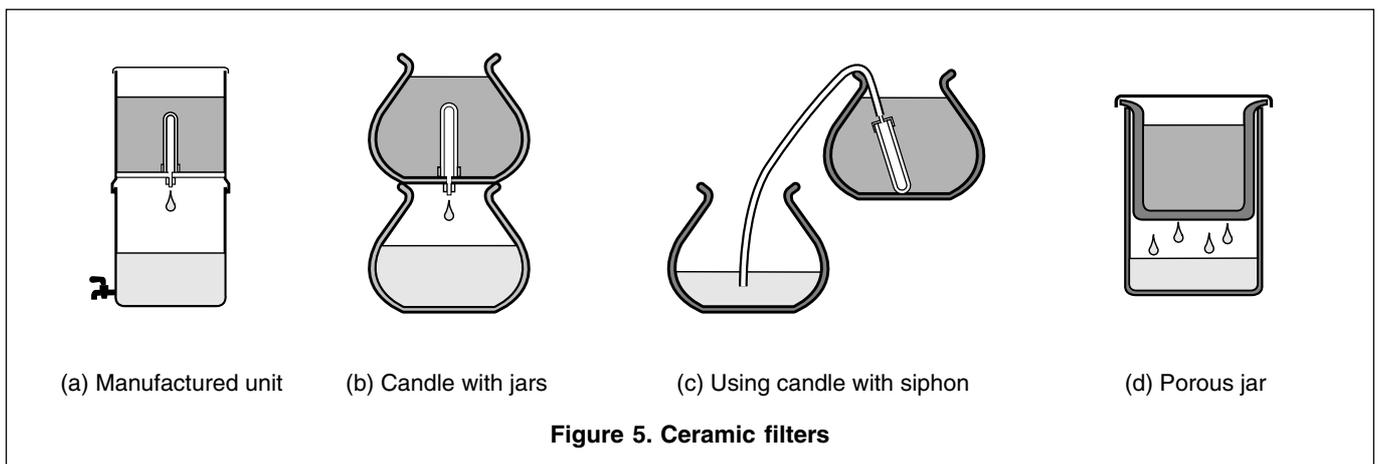


Figure 5. Ceramic filters

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Fluoride removal

Excessive fluoride (above 1.5mg/l), which is sometimes found in groundwater, can damage bones and teeth. There are a wide variety of systems for reducing excessive fluoride and the effectiveness of each depends on various factors such as the initial concentration of fluoride, the pH of the water (a measure of the acidity or alkalinity) and the hardness of the water. The methods most suited to domestic treatment in low-income communities include lime softening or the use of pre-treated bone. One system which seems to have had considerable success in the field is the Nalgonda system which combines the use of lime (to soften the

water) with alum (as a coagulant) followed by settlement; the technique is used simultaneously with chlorination to ensure disinfection of the water.

Arsenic removal

Dangerous levels of arsenic can be found naturally in groundwater and surface water, but can also result from industrial pollution. Excessive amounts are toxic to humans, resulting in various diseases including cancer. High levels are a growing problem in groundwaters in some countries like Bangladesh. The effectiveness of any treatment process depends on the specific form of arsenic found in the water and the type of coagulant and filtration material used to

purify the water. Important research is presently being carried out into arsenic removal to find appropriate solutions. Treatment processes which include the addition of lime to soften the water, followed by settlement, have been in use for some time.

Combining treatment methods

Methods used to remove chemicals do not necessarily also remove pathogens. For this reason, disinfection or filtration using a ceramic filter or a well-designed slow sand filter, is likely to be necessary to produce an acceptable quality of drinking-water.

Further reading

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Coagulation, flocculation

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Jahn, Samia Al Azharia, *Proper use of Natural Coagulants for Rural Water Supplies: Research in the Sudan and a guide for new projects*, GTZ, Eschborn, 1986.

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Iron removal

Ahmed F. and P.G. Smith, 'Design and performance of a community type iron removal plant for hand pump tubewells', *Journal of the Institution of Water Engineers and Scientists*, Vol.41, 1987.

Tyrrel S., Gardner S., Howsam P. and Carter R., 'Biological removal of iron from well-handpump water supplies', *Waterlines*, Vol.16, No.4, IT Publications, London, 1988.

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NEERI, *Defluoridation*, National Environmental Engineering Research Institute, Nagpur, 1987.

Relevant technical briefs

(Relevant Technical Brief numbers are shown in the text preceded by TB.) 11 Rainwater Harvesting; 15 & 21 Slow sand filter design; 17 & 19 Health, water and sanitation (1 & 2); 40 Desalination; 46 Chlorination of community water supplies; 47 Improving pond water; 58 Household water treatment 1.

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