Design, operation and maintenance considerations of horizontal flow roughing filters

by T.S.A. Mbwette and M. Wegelin

Horizontal flow roughing filters preceding slow sand filters are a promising way to make water safe in the rural areas of developing countries. The authors offer this thoughtful discussion of the principles and development of the technology.

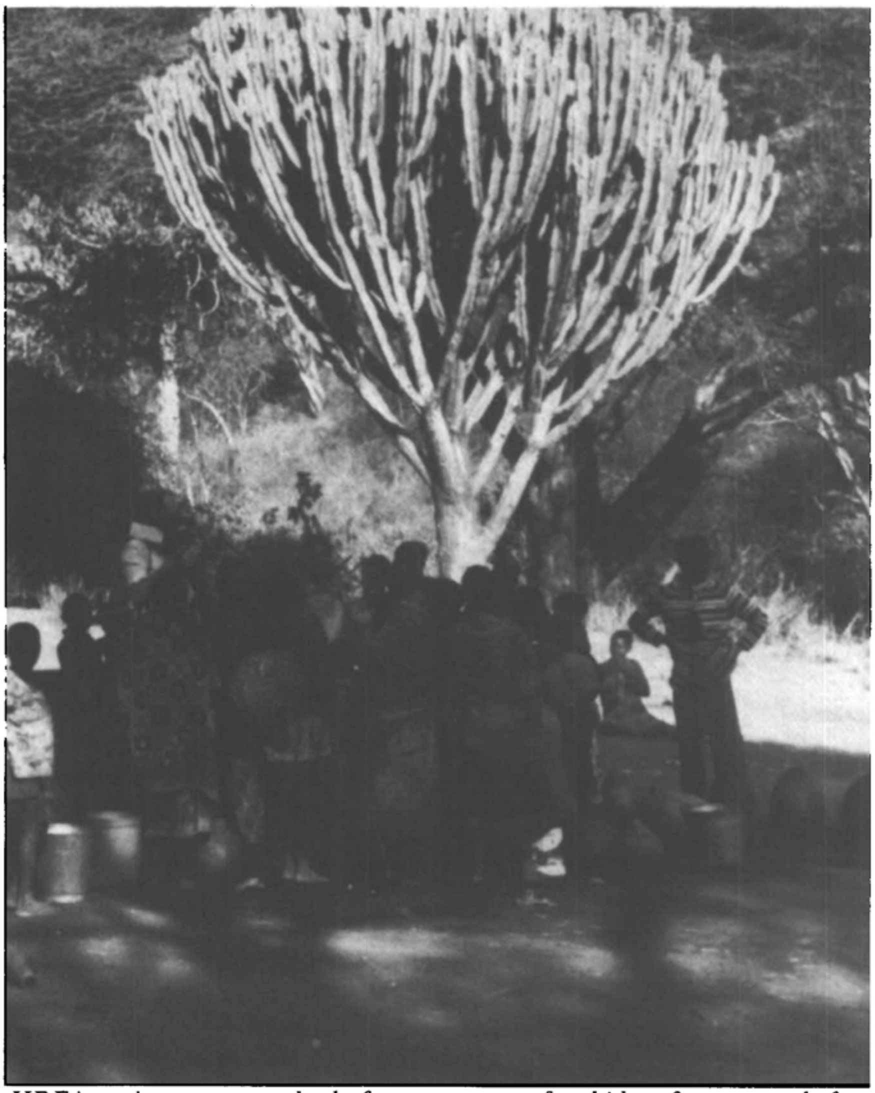
ROUGHING FILTRATION is a process in which relatively coarse grains are used to filter water, but horizontal flow roughing filters (HRF) are units through which water flows horizontally along a coarse to fine sequence of porous media with the primary aim of improving its quality. This article reviews the design, operation and maintenance aspects of HRF preceding SSF on the basis of tests carried out in Tanzania and Switzerland coupled with experience gained in operation of several plants already built in Tanzania. It must be emphasized that the experiences reported are limited to the operation of small-scale rural water supply schemes only.

Design aspects

Design considerations are first reviewed on the basis of general philosophy and optimization strategies, then design guidelines are given with respect to size, filter media and filter run periods.

Early designs of HRF were based on the assumption that filter boxes had to have enough volume to retain all of the materials deposited during the filter run. In this case, the filter load became the limiting factor, and this generally resulted in higher construction costs. Emptying out the accumulated deposits on and around filter grains by intermittent hydraulic flushing tested at IRCWD has made the filter load factor less critical. The water quality minimum, however, becomes more critical in the sense that the filter length provided has to guarantee filtration to an acceptable effluent quality throughout the year.

Although in practice it is not easy to carry out routine suspended solids analysis, judgement of a good HRF design is largely dependent upon its stability to reduce its concentration to levels acceptable for operation of the SSF — usually less than five parts per million. Therefore, a good designer has to observe the required effluent standards and daily output, acceptable filter run times and the maximum allowable filter resistance across the bed. According to the filtration model adopted, a technical and economic optimization has to be carried out with respect to the filtration rate, available filter media sizes, cross-sectional area and individual length of the filter media. In practice, small-scale pilot plants (conduit models or lined HRF units) should be set up to determine acceptable filtration rates, suitable sizes and



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HRF is an important method of pretreatment of turbid surface waters before slow sand filtration in rural communities.

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individual lengths of filter media and the filter run of HRF. If circumstances allow, data from pilot tests can be processed locally in a computer so as to perfect the design and double-check preliminary designs made on the basis of field test data only.

Design guidelines

Because the major transport mechanism in HRF is sedimentation, long detention times require operation of HRF at low filtration rates when filtering raw water with high amounts of suspended solids. With respect of the filter media size, the use of too fine grains (i.e. having a diameter less than 5mm) is not desirable because of the high head losses associated with them, and also due to the reported difficulty in cleaning off the accumulated deposits. Laboratory and field tests carried out indicate that the most effective filter media have a diameter between five and 30mm, and that the total filter length is between six and 12m. Three or four gravel sizes should be present in any HRF unit.

Table 1 gives the recommended tentative design guidelines with respect to filtration rates, individual media lengths and grain sizes for two broad ranges of suspended solids concentration. The height and width of HRF boxes are influenced by plant capacity, structural, operational and maintenance requirements. It is recommended that the boxes lie within the range of one to 1.6, and 1.5 to 5m, respectively. Because research has shown that the shape and surface texture of filter media have a negligible influence on the filtration co-efficient, crushed gravel, shingles, plastic modules or chips, broken burnt bricks, or exceptionally, even charcoal may all be used as HRF media. To minimize maintenance requirements, filter run times of between six months and two years should be provided.

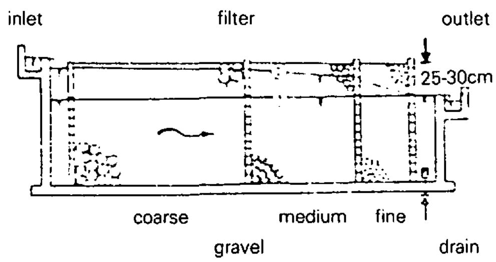
Table 1. Tentative design guidelines

Approximate suspended solids concentration in raw water (ppm)	*More than 150*	*50 - 150*
Filtration rate (m/h)	0.5 - 0.75	0.75 - 1.0
Individual filter lengths for grains with diameter:		
30-15mm	3 - 5m	3 - 4m
15-10mm	2 - 4m	2 - 3m
10- 5mm	1 - 3m	1 - 2m
Effluent suspended solids concentration (ppm)	Less than 5	

Lay-out and construction details

In order to allow for continuous treatment during maintenance, at least two HRF units should be provided in any plant. An HRF can either be constructed with side walls completely or partially buried in the ground, or they can be built as an excavation below ground. Resulting transverse cross-sections would either be rectangular or trapezoidal. The most modest HRF is a lined trench in which no leaking from or into the HRF box can occur. The use of prefabricated reinforced concrete tiles or laid linings (concrete or ferrocement) is recommended. Side walls can be constructed from burnt bricks, concrete blocks, stone masonry or reinforced concrete walls in extreme cases. In terms of the plan lay-out, an HRF may be designed in either a rectangular or an annular shape. To date, most of the HRF units constructed are rectangular. The idea of design of an annular-shaped HRF was meant to exploit the traditional experience of masons in construction of circular reinforced wall masonry water storage tanks that are used in Tanzania.

Overflow accessories provided should keep the maximum flow of water five to 10cm below the top of the filter media to prevent the growth of algae. This means that in addition to allowing a maximum head loss of say 20cm across the filter at the end of the filter run, the maximum level of flow of the effluent weir has to be 25 to 30cm below the top of the filter media as shown in Figure 1. Water-tight construction joints should be provided in the foundation slab and the side walls to allow for shrinkage and settling. To ease maintenance, the foundation slab should have a longitudinal slope of 1 or 2 per cent in the direction of flow. A washing-slab ending in a main side drain should be provided on one side of the HRF. Either a simple false bottom with built-in troughs (see Figure 2, lower left) or perforated pipe systems should be included in order to help in flushing out deposited matter by draining the water table within 10 to 15 minutes. To avoid depletion of oxygen due to the biochemical and oxidation processes reported to occur in HRF, a cascade or any other simple aerator should be provided before the SSF units.



(1) water table in clean filter (at begin of filter operation)
(2) water table in loaded filter (at end of filter operation)

Figure 1. Head-loss pattern across the HRF.

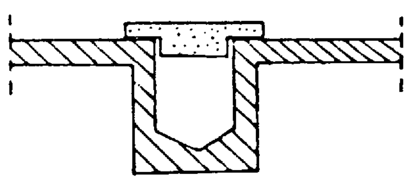


Figure 2. Cross-section of a typical semi-covered built-in trough.

Operation and maintenance considerations

The filter and media must be cleaned thoroughly before filling the filter box for the first time. In any case, during the first three or four days after commissioning the HRF, the effluent should not be used in order to allow for the initial necessary ripening period. In general, intermittent operation of HRF does not lead to any deterioration of effluent quality if a smooth re-start in terms of the filtration rate is ensured. To exploit the advantages of the hydraulic removal of deposits, the operator should drain the filter through the underdrainage at regular intervals. The operator should also keep the normal filtration rate constant by checking and adjusting flow levels over the in-flow and out-flow 'V' notch weir.

Simple water quality analysis on raw and treated water (turbidity and filterability) and filter-resistance measurements should be done at least once a week. If conditions allow, an effluent sample should be taken for bacteriological analysis every month or two. Besides extending the filter run by intermittent drainage, at some stage (perhaps after two or more years) the proportion of sticking deposits in the filter box will be so high that the filter media must be drained, dug out and washed. The filter media should be washed immediately after removal from the box to avoid fouling or drying up which would make washing more difficult. Ideally the washing slab should be located just beside the HRF box in order to minimize the movement of the media.

Economic considerations

An evaluation of construction costs of HRF units with design capacities ranging from 70 to 750 cubic metres to be located in Tanzania, Kenya and Indonesia has shown that construction costs range from US$60 and $80 per cubic metre of design capacity. A considerable amount of this cost can be saved if community participation in the form of free labour can be mobilized. Operation and maintenance costs would include the salary of the operator, together with the cost of cleaning the filter media manually in case paid labour is needed. For the case of Tanzania, on the basis of 1983-4 prices, such annual costs would not exceed $2 per cubic metre of HRF media. In practice, well-organized communities can be expected to be willing to clean the filter media once every year or two. At present, a number of treatment plants with HRF units preceding SSF have been constructed in Thailand, Tanzania, Indonesia and Australia. More schemes are planned to be constructed in Peru, Kenya and Tanzania.

Horizontal flow roughing filtration is an important method of pretreatment of turbid surface waters before slow sand filtration in rural communities. It can be applied to the speed realization of the goals of the Water Decade in developing countries. The combination of HRF with slow sand filters makes it possible to ensure the best use of locally available resources, and so represents a water treatment technology highly suitable for developing countries. Although considerable research has been done in the field of HRF to date, there is still a need to combine experiences from all the practitioners involved to come up with more universally acceptable guidelines.