DESIGN, OPERATION AND MAINTENANCE CONSIDERATIONS OF HORIZONTAL FLOW ROUGHING FILTERS PRECEDING SLOW SAND FILTERS

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Abstract

The paper mentions some of the reported uses of Horizontal Flow Roughing Filters (HRF) in drinking water treatment plants in Europe before briefly reviewing research activities carried out in the use of HRF prior to Slow Sand Filters. Design, operation and maintenance aspects of HRF are reviewed on the basis of the laboratory and field tests carried out in Tanzania and Switzerland, respectively in addition to experience gained in operation of a number of plants already built to date. Design aspects are introduced from the point of view of its philosophy and optimization strategies before design guidelines are given. Important layout and construction details are also discussed. Operation and maintenance activities involved are outlined prior to reviewing economic aspects. At the end, conclusions regarding the viability of application of HRF in rural water supply schemes and the need to combine the findings of all researchers are given.

INTRODUCTION

Whereas roughing filtration is a process in which relatively coarse grains are used to filter water, Horizontal flow Roughing Filters (HRF) are units in which water is flown horizontally through such a coarse to fine sequence of porous media with the primary aim of improving its quality. Detailed descriptions of main features of HRF can be found in [1-3]. HRF were reported [4] to have been applied in drinking water treatment in the UK as early as 1804, elsewhere in Europe, HRF have been/are applied in pretreatment of ground water recharge slow sand beds in West Germany [5, 6] and Switzerland [7]. In England, the use of HRF prior to Slow Sand Filters (SSF) at Fobney water works has been reported [8].

Thanh *et al* [9 - 11] has reported research work carried out in the use of HRF prior to SSF in Thailand. Similar research activities carried out in Tanzania have been reported previously [1, 2, 12 - 16, 21, 22]. Recently, Wegelin *et al* [17, 18] reported further laboratory research work in HRF done at the International Reference Centre for Wastes Disposal (IRCWD) in Switzerland. The University of Surrey has reported [19, 20] research work first done in the UK and subsequently in Peru in pretreatment of SSF inlet waters by HRF. This paper 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 emphasised that experiences reported are limited to operation of small scale rural water supply schemes only.

DESIGN ASPECTS

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

DESIGN PHILOSOPHY AND OPTIMIZATION STRATEGY

The filtration efficiency of HRF can be described by rigorous mathematical models as done in [18] or by a simplified first order equation which can be used for estimation of clean bed removal efficiencies in HRF [3]. The fact that it is mathematically easier to model physical rather than biochemical quality parameters calls for care in the use of such models in design work, especially the need to know the limits of applicability. Early designs of HRF [1] were based on the assumption that filter boxes had to have enough volume to retain all materials deposited during the filter run. In this case, the solids deposition factor or filter load σ (gSS/1) became the limiting criterion and this generally resulted into higher construction costs. The enhancement of collapse of deposits formed on filter grains by intermittent hydraulic flushing out observed at IRCWD [2,3] has made the solids deposition factor less critical. However, the quality criteria have become more critical in the sense that the filter length and media sizes provided have to guarantee production of an acceptable effluent quality throughout the year.

Although in practise it is not easy to carry out routine suspended solids analysis [16], judgement of a good HRF design is largely dependent upon its ability to reduce its concentration to levels acceptable for operation of SSF (usually less than 5 ppm.). Therefore, a good designer has to observe the required filtrate standards and daily output, acceptable filter run times and the maximum allowable filter head loss across the bed. According to the filtration model adopted, a technical cum 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 fractions. In practise, small scale pilot plants (conduit models or lined HRF units) should be set up to determine acceptable filtration rates, suitable sizes and individual lengths of filter media and the filter run times of HRF. If circumstances allow, data from the pilot tests can be processed locally in a computer so as to optimize the design and counter - check preliminary designs made on the basis of the field test data only.

GENERAL DESIGN GUIDELINES

Due to the fact that the major transport mechanism in HRF is sedimentation [1, 2, 14], detention time requirements necessitate operation of HRF at low filtration rates when filtering raw water with high suspended solids. With respect to the filter media size, the use of too fine grains (i.e. diameter less than 5 mm.) is not desirable due to the high head losses associated with them and also due to the reported [2] prevention of occurrence of the observed deposit collapse mechanisms. Laboratory and field tests carried out so far seem to limit the diameter of filter media between 5 and 30 mm. and the total filter length between 6.0 and 12.0 m. Three or four gravel fractions should be provided in any HRF unit.

Table.1 gives the recommended tentative design guidelines with respect to filtration rates, individual media fraction lengths and grain sizes for two broad ranges of suspended solids concentration. The individual height and width of HRF boxes are influenced by plant capacity, structural, operational and maintenance requirements and are recommended to lie in the range of 1.0 to 1.6 m. and 1.5 to 5.0 m, respectively [1,3]. Because research [2, 13, 14] has shown that the shape and surface texture of filter media have negligible influence on the filtration coefficient, inert gravel, plastic modules or chips, broken burnt bricks or exceptionally with care charcoal [21] can be used as HRF media. To minimize maintenance requirements, filter run times of at least six months 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 - 15 mm. 15 - 10 mm. 10 - 5 mm.	 3 - 5 m. 2 - 4 m. 1 - 3 m.	 3 - 4 m. 2 - 3 m. 1 - 2 m.
Effluent suspended solids concentration (ppm.)	Less than 5	

PLANT LAYOUT AND CONSTRUCTION DETAILS

In order to allow for treatment continuity during maintenance, at least two HRF units should be provided in any plant. HRF can either be constructed with side walls completely/partially burried in the ground or they can be built as an excavation below ground surface. Resulting transverse cross sections would either be rectangular or trapezoidal. The most modest HRF is a lined trench in which no leakages from/into the HRF box can occur. The use of prefabricated reinforced concrete tiles or in-situ laid linings (concrete or ferrocement) is recommended. Side walls can be invariably constructed from burnt bricks, concrete blocks, stone masonry or reinforced concrete walls in extreme cases. In terms of the plan layout, HRF can be designed with either rectangular or annular shape. To date, most of the HRF units constructed are rectangular. Apart from ensuring optimum space utilization for a large number of HRF units, the idea of design of annular shaped HRF is meant to exploit the experience of masons in construction of circular reinforced wall masonry water storage tanks for the case of Tanzania.

Overflow accessories provided should keep the maximum flow of water 5-10 cm. below the top of filter media so as to prevent the growth of algae. This means that in addition to allowing a maximum headloss of say 20 cm. across the filter at the end of the filter run time, the maximum level of flow of the outlet weir has to be 25-30 cm. below the top of the filter media as shown on Fig. 1. Water-tight construction joints should be provided in the foundation slab and the side walls to allow for shrinkage and differential settlements. To ease maintenance activities, the foundation slab should have a longitudinal slope of 1-2% in the direction of flow. A washing slab ending into a main side drain should be provided on one side of the HRF. Either a simple false bottom with built-in troughs (Fig.2) or perforated pipe systems should be included in order to help in flushing out deposited matter by draining the water table within 10-15 minutes. To avoid depletion of Oxygen due to biochemical and oxidation processes reported to occur in HRF [9, 20], a cascade or any other simple aerator should be provided before the subsequent SSF units.

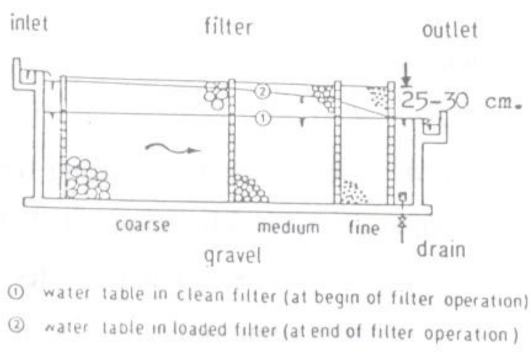

Fig.1 Head Loss pattern across the HRF

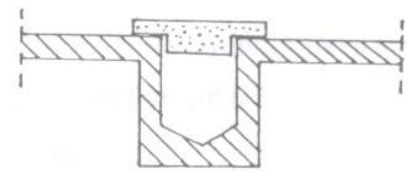

Fig.2 Cross section of a typical semi-covered built in trough

OPERATION AND MAINTENANCE

The filter media has to be cleaned thoroughly before filling in the filter box for the first time. In any case, during the first three or four days of commissioning the HRF, the filtrate should be led to waste in order to allow for the initial ripening period reported to exists [9, 14, 20]. In general, intermittent operation of HRF does not lead to deterioration of effluent quality if a smooth re-start in terms of the filtration rate is ensured. To exploit the advantages of hydraulic scooping down 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 inlet and outlet vee notch weirs. Simple water quality analysis [1, 3, 14] on raw and treated water (turbidity and filterability) and filter head loss measurements should be done at least once a week. If conditions allow, a filtrate sample should be taken for bacteriological analysis say once a month or two. Besides extending the filter run time by intermittent drainage, at some stage later (say after two or more years), the proportion of sticking deposits in the filter box will be so high that the filter media has to 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 cumbersome. The washing slab should preferably be located just besides the HRF box in order to minimize movement of media [1, 22].

ECONOMIC CONSIDERATIONS

An evaluation of construction costs of HRF units with design capacities ranging from 70 to 750 m^3/d located/planned to be located in Tanzania, Kenya and Indonesia [1, 3, 22] has shown that construction costs range in between 60 and 80 U.S. \$ per m^3/d design capacity. A considerable amount of this cost can be saved if community participation in form of free labour can be mobilized. Operation and maintenance costs would

comprise of the salary of the operator and the costs of cleaning the filter media manually in case paid labour is employed. For the case of Tanzania, on the basis of 1983/84 prices, such annual costs would not exceed 2 U.S. \$ per m^3 HRF media volume installed [22]. In practise, well organized communities can be expected to be willing to clean the filter media once in a year or two.

At present, a number of treatment plants with HRF units preceding SSF have been constructed in Thailand [9 - 11], Tanzania [1, 2, 14, 15, 17, 22], Indonesia and Australia [3]. More schemes have been planned to be constructed in Peru [20], Kenya [3] and Tanzania.

CONCLUSIONS

1. Horizontal flow Roughing Filtration is an important unit operation for pretreatment of turbid surface waters before SSF in rural communities. It can be applied to speed up realization of the water and sanitation services provision goals of many developing countries.

2. The process combination HRF/SSF makes it possible to ensure one of the best uses of locally available resources and hence represents a water treatment technology highly suitable for developing countries.

3. Although a lot of research has been done in the field of HRF to date, there is still a need to combine experiences from all the workers involved so as to come up with more universally acceptable guidelines.

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SYMBOLS AND ABBREVIATIONS USED

σ	.....	.....	Solids deposition factor or filter load
gSS/l	.....	.....	grams suspended solids per litre.
HRF	.....	.....	Horizontal flow Roughing Filter(s)/Filtration
IDRC	.....	.....	International Development Research Centre.
IRCWD	.....	.....	International Reference Centre for Wastes Disposal.
ODA	.....	.....	Overseas Development Administration, UK.
ppm	.....	.....	parts per million
SSF	.....	.....	Slow Sand Filter(s)/Filtration.