IRCWD NEWS

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Horizontal-flow Roughing Filtration: An Appropriate Pretreatment for Slow Sand Filters in Developing Countries

In many developing countries contaminated surface water constitutes the only source of water for a large part of the population. In order to make this water safe for drinking, treatment is often necessary. On account of its simple construction and operation, Slow Sand Filtration (SSF) has become a most appropriate technology for water treatment. The greatest drawback of SSF is its successful application with raw water containing only few suspended solids since there is a high risk of filter clogging after already a short time.
In tropical countries, river waters contain a high concentration of suspended solids especially in the wet season. Hence, pretreatment of such waters is often necessary before applying Slow Sand Filters. The conventional way of separating suspended solids consists in a flocculation and a sedimentation step. This process is rather difficult to implement in developing countries since it often requires foreign currency and skilled personnel to apply the chemicals.

Martin Wegelin *a Swiss sanitary engineer who has been working at the University of Dar es Salaam, Tanzania before joining IRCWD in 1982, presents an alternative pretreatment method with the use of a Horizontal-flow Roughing Filter (HRF). This method has been tested in the laboratory of the University of Dar es Salaam and the purification potential of such filters confirmed by subsequent field tests in Tanzania. For the past two years IRCWD, for which the Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG) is the host institution, has been testing the HRF process on a laboratory scale. These investigations lead to a better understanding of the mechanism taking place in the HRF, to practical design criteria and to the development of a filtration model as a tool for the design of HRF.*

Institutions involved in water treatment projects in developing countries are cordially invited to cooperate with IRCWD in applying and promoting the suggested treatment schemes in different countries.

1. Introduction

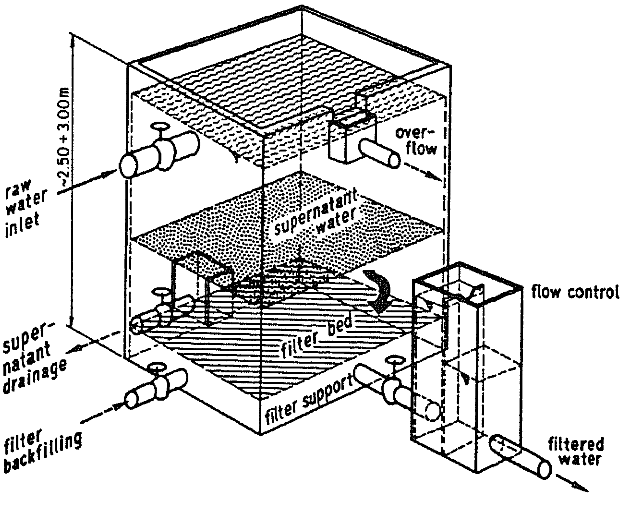
Not everybody is blessed with pure and safe water from a spring or groundwater well. A large part of mankind is forced to use surface water which is often unattractive or even hazardous to health. Exposed to contamination, surface water is an excellent carrier of water-borne diseases. Outbreaks of cholera or typhoid fever are possible consequences of fecal pollution.

In order to avoid such epidemics, natural water purification processes were introduced at the beginning of last century. Contaminated water was filtered through a layer of sand and became bacteriologically safe. This experience gave way to a fascinating water treatment technique, i.e. Slow Sand Filtration (SSF). The first large SSF were installed by the Chelsea Water Company in London in 1829. Many other European cities adopted this technology and were able in combination with other sanitation improvements to eradicate water-borne epidemics. Even today, numerous water supplies in industrialised countries are still using SSF as part of their water purification systems.

1.1 Slow Sand Filtration as appropriate technology

SSF offers the great advantage of being safe and stable, simple and reliable and can therefore be considered a most appropriate water treatment technology in developing countries. Filter construction makes extensive use of local material and skills. Construction as well as operation and maintenance of the filters is easy and requires only limited professional skills. Neither mechanical parts nor chemicals are necessary for SSF. The treated water is of high quality since bacteria are almost completely removed. A SSF is schematised in Fig. 1. More information on SSF for practical use is compiled in a design and construction manual published by IRC, Rijswijk, The Netherlands (Ref. 1). This comprehensive manual emerged from an SSF integrated research and demonstration project carried out by the Centre in cooperation with institutions in six developing countries.

Fig. 1:
Main Features of a Slow Sand Filter (SSF)



All the advantages of SSF should favour the use of this technology. However, practical experience in developing countries reveal that many SSF installations are facing serious operational problems or are even out of operation. One major reason for the existing situation is caused by the poor raw water quality fed to the filters. SSF is very sensitive to particulate matter which, at high concentration, will block the filter after a short time. SSF will therefore operate only satisfactorily with raw water of low turbidity (< 10 NTU). Filtration of raw waters with higher turbidities will cause a rapid increase of the filter resistance. Short filter runs and frequent cleaning is the consequence of poor raw water quality. The most desired biological activities of the filter required for bacteriological water improvement will therefore be seriously affected, and application of SSF becomes very questionable under such conditions.

Throughout or during part of the year, most flowing surface waters in the tropics are of a higher turbidity than the standard required by SSF. Therefore, for a reasonable SSF operation, raw water pretreatment is often necessary to reduce turbidity or more specifically to separate the suspended solids responsible for part of the turbidity.

1.2 Pretreatment processes

Sedimentation and filtration are the most common processes used to reduce solid mater. **Plain sedimentation** in conventional settling tanks enables the separation of solids larger than about 20 μm. Smaller particles known as colloidal solids are only partially retained by sedimentation tanks. However, a large percentage of the solid matter found in river water belongs to this fraction. The effluent of conventional sedimentation tanks will therefore hardly meet the high standard required by SSF.

Flocculation, which is achieved by addition of chemicals, will accelerate the process of sedimentation. The suspension is destabilised and, as a result, the fine particles form flocks of a higher settling rate. Great difficulties are often connected with the provision and distribution of chemicals. For correct dosage of flocculants and flocculant aids and adequate operation of the installations, considerable skill is necessary not to hamper floc formation or destroy the weak flocs. Process instability, dependency on regular chemical supply and the need for highly qualified personnel make a reliable application of this process for rural and small urban water supplies more than questionable.

Prolongued storage operates on a time factor. Even the smallest particle which is heavier than water will settle although at a very slow rate. A clay particle of 1 μm diameter will for example require about two weeks to settle 1 m in still waters. Taking disturbances caused by wind and temperature variation into account, prolongued storage will only be effective at retention times of 1–2 months. The size of such reservoirs compared to the area required for SSF installations is multiple (approx. 50 times larger). Additionally, the risk of excessive algal growth might create new operational problems such as the separation of algae or the elimination of by-products. Therefore, prolongued storage is usually used only in multipurpose projects, e.g. in combination with irrigation.

In **rapid sand filters,** water flows vertically through an approx. 1 m thick filter of porous media. These filters are able to retain suspended matter to a large extent, but their silt storage capacity is relatively small. This in turn makes frequent filter cleaning (at intervals of usually 1 to 4 days) necessary. The filter bed of rapid sand filters is cleaned by a backwash process requiring besides energy, rather complicated mechanical equipment. Due to its high mechanisation, the level of rapid sand filtration is technically higher than the simple SSF process. Hence, this filter type is hardly appropriate for rural water supplies.

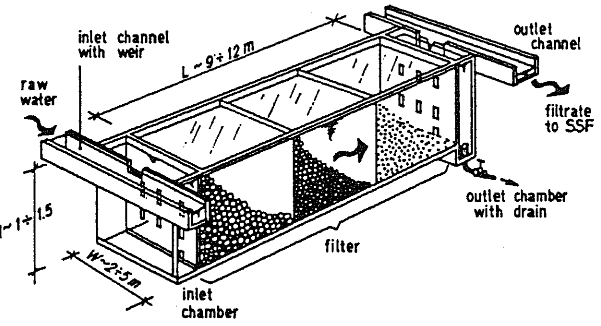
Horizontal-flow Roughing Filtration (HRF) changes the flow direction from vertical to horizontal. Consequently, the thickness of the filter bed for HRF is no longer limited to 1 m as a result of structural and operational constraints. Filter beds of approx. 10 m length and small hydraulic loads enable filter operation of several months. Filter cleaning is carried out manually. The absence of mechanical equipment and its simple operation technique favours this process to be applied prior to SSF. A more detailed description of this filter type is given in the following chapter.

Infiltration galleries work on the same principle as HRF. Their structures, however, is a combination of surface water intake and its pretreatment. The water quality of the effluent of such galleries usually meets the standard required by SSF. Cleaning and maintenance of infiltration galleries, however, might create access problems.

2. Description of Horizontal-flow Roughing Filtration

The schematic lay-out of a HRF is illustrated in Fig. 2. The main feature of such a filter consists of a box of several sections filled with filter material of different sizes. The raw water falls over a weir into an inlet chamber in which the coarse solids will settle and the floating matter retained by a separation wall. However, the main purpose of this inlet structure is the even flow distribution over the cross-section of the filter. The water passes through the perforated separation wall and flows in a horizontal direction through a sequence of coarse, medium and fine filter material. Thereafter, the pretreated water is collected by an outlet chamber, discharged for flow measurements over a weir into an outlet channel and conveyed to the SSF.

Fig. 2:
Main Features of a Horizontal-flow Roughing Filter (HRF)



The length of the filter box (usually between 9 and 12 m) depends on the raw water quality, the hydraulic filter load and on the size of the filter media. In order to allow comfortable manual cleaning of the filter, its height will be limited to about 1.5 m. The width of the filter box depends finally on the required filter capacity and varies normally from 2 to 5 m per unit.

The box is filled with a filter medium different in size. The coarsest material should be around 25 mm, and the finest gravel not smaller than 4 mm.

The bulk of solid matter in the raw water will be retained by the first coarse filter packs. The last filter compartment should act as polisher and remove the last traces of solid matter in the raw water. Each gravel pack becomes gradually loaded with retained solid matter until filter efficiency is exhausted which, under ideal HRF lay-out, should be reached by all gravel packs simultaneously.

Filter efficiency can be restored to a certain extent by filter drainage as described in Chapter 3.5. After a filtering period of half a year or longer, which is dependent on the raw water quality and lay-out of the filter, the accumulated solid matter has to be removed. Filter cleaning is carried out manually by excavating the filter material, washing the media and refilling the filter box. This operation can easily be carried out with village participation or by casual labourers, thereby requiring no mechanical equipment.

3. Practical experience with HRF

3.1 Experience in Europe

Several water treatment plants in Europe are operating HRF in combination with SSF. However, these installations are used for artificial groundwater recharge and not for direct water supply. Furthermore, the extracted river water is of normally low turbidity and suspended solids concentration. Extraction is stopped during high turbidity due to floods. In such periods, the storage capacity of the aquifer guarantees a continuous water supply to the consumer. Prefilters used in Europe are consequently loaded with very low suspended solids concentrations as summarised for three different plants in Table 1. Therefore, the homogeneous filter beds (one gravel fraction only) can be run at rather high filtration rates.

Table 1:
Examples of HRF in Europe

Name of plant	Country	Name of river	Susp. solids conc. (mg/l) mean	max.	filter length (m)	filtration rate (m/h)
Dortmund	W. Germany	Ruhr	8	20	50-70	10
Aesch	Switzerland	Birs	7	40	15	5-8
Graz	Austria	Andritzbach	5	20	10	4-14

3.2 Applicability of HRF in tropical countries

Uneven annual rainfall distribution, high temperature fluctuations, specific chemical water characteristics (e.g. low hardness, humic substances), deforestation and land cultivation methods furthering soil erosion, are the main causes of highly turbid and silted surface water in tropical countries. In the tropics, rivers carry a much higher load of suspended matter than in temperate climates. High concentrations of suspended solids are encountered especially during the rainy season. The risk of epidemics is greater during the wet season as a result of washed off faeces which had not been disposed of properly. Therefore, reliable and uninterrupted water treatment is of paramount importance especially during this season. In the tropics, water supply installations using surface water usually have to treat highly silted water and maintain operation even during peak loads. Studies on the design and performance of HRF under tropical conditions were conducted at the Asian Institute of Technology (AIT), Bangkok, Thailand, at the University of Dar es Salaam (UDSM), Tanzania and at the Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG), Dubendorf, Switzerland. The investigation results of these three institutes with HRF are briefly reviewed hereafter.

3.3 Experience in Thailand

In 1977 AIT ran at its premises laboratory and pilot scale filtration tests with HRF and SSF. Surface water ranging from 20 to 120 NTU in turbidity was used from a canal near the laboratory. A preliminary test was carried out with a prefilter of 1.5 m length comprising gravel packs of 0.30 m length and filter material of an effective size varying from 9.1 to 2.8 mm. The prefilter was operated at a filtration rate of 0.6 m/h and produced a filtrate of about 15 NTU. The subsequent SSF run at 0.15 m/h clogged after 44 days. In another test, a prefilter of 5 m length containing 7 filter packs and effective filter sizes ranging from 15.7 to 3.4 mm was installed. Operated at 0.6 m/h, turbidity of the prefiltered water varied from 10 to 20 NTU. The following SSF run at 0.15 m/h revealed a headloss of 57 cm after 55 days of continuous operation.

Encouraged by the good results of these filter tests, 3 full-scale demonstration schemes were set up in the villages of Jedee-Thong, Ban Bangloa and Ban Thadindam. Surface waters of turbidities up to 275 NTU are pretreated with HRF of approx. 5 m filter length comprising 6 gravel packs with effective grain sizes ranging from 15 to 2.6 mm. The prefilters operate at filtration rates between 0.5 and 1 m/h, whereas the SSF run at a rate of 0.15 m/h. The available records (Ref. 2–4) report good HRF performance, thus enabling SSF filter runs of several months. Apart from turbidity, several other water quality parameters were recorded. The good bacteriological quality of the water produced by the filters is mentioned explicitly. The projects were supported by IRC Rijswijk and IDRC (International Development Research Centre, Ottawa, Canada).

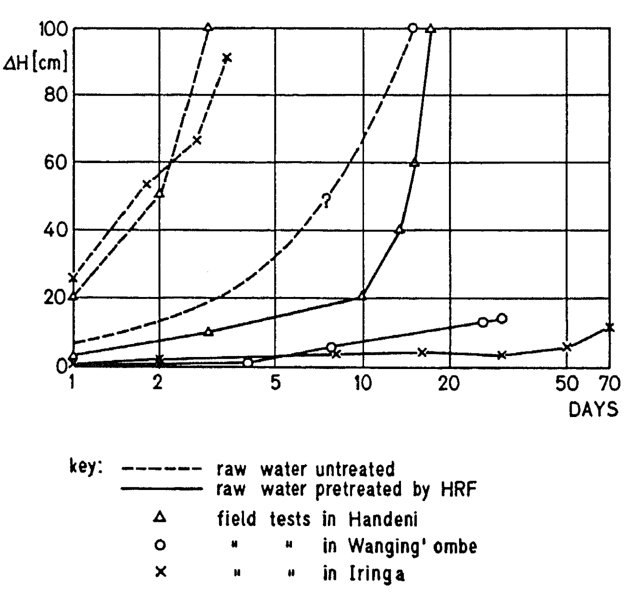
3.4 Experience in Tanzania

Faced with operational problems at different SSF plants in Tanzania, the UDSM embarked on a research project in 1979. A first survey on the surface water quality in Tanzania gave evidence that most rivers in this country required pretreatment prior to SSF application. Negative experiences with chemical pretreatment of raw water involving flocculation and sedimentation revealed the unreliability of this process under rural conditions. Therefore, the research project aimed at developing a sound and self-reliant pretreatment method mainly based on physical processes.

Laboratory tests with a water mixture of tap water and water-borne sludge originating from domestic tanks of a 60 NTU turbidity revealed that sedimentation alone could not meet the standards required by SSF. Experiments with vertical filter columns of 1 m depth filled with gravel varying from 1 to 64 mm in size and filtration rates from 0.5 to 8 m/h, confirmed the sensitivity of the filter performance with respect to the flow conditions in these filters. Remarkable turbidity reduction was experienced with flow velocities lower than 2 m/h. However, vertical-flow roughing filters are unsuitable as pretreatment units for rural application. Due to their small silt storage capacity and consequently short filter runs, frequent cleaning is necessary and requires sophisticated equipment and skilled labour. A shift of the flow direction from vertical to horizontal can eliminate these disadvantages. Therefore, an open channel of 15 m length was filled with 3 gravel fractions of 16–32, 8–16 and 4–8 mm in size. Filtration rate varied from 0.5 to 8 m/h, whereas turbidity of the water mixture was maintained at 60 NTU. Under the given conditions, the tested HRF produced an effluent quality of less than 10 NTU at filtration rates of 0.5 and 1 m/h only.

Field tests at three different sites were carried out to verify the good laboratory results. At Handeni and Wanging'ombe, portable PVC pipe models of 250 mm diameter were installed as HRF and SSF units, whereas in Iringa, a large-scale pilot plant was constructed with a HRF (cross section 1.6 x 1.0 m, filter length 10 m) and a SSF (4 m^2 filter area) in addition to different pipe models. Fig. 3 summarises the filter resistance of different SSF fed either with untreated river water or with water pretreated by HRF. From the graphs it is obvious that SSF cannot be applied without pretreatment of the river waters examined. The respective filter runs last from a few days up to 2–3 weeks, but reasonable operation times for SSF are in the range of 2–3 months or more. With properly cleaned SSF filter beds and adequately pretreated raw water, the filter resistance of different SSF at 0.2 m/h filtration rate was less than 20 cm after 1 month of continuous operation. Hence, running times of 2–3 months could easily be achieved. Most filtration tests were run as short-term experiments to investigate the influence of filtration rate and gravel size on filter efficiency. However, a HRF pipe model (Ø 250 mm; gravel sizes 32–16, 16–8, 8–4, 4–2 mm; gravel packs of 40 cm length each) was used for several long-term filtration tests to determine the silt storage capacity. Filter loads (stored solid matter per litre filter volume) of 35 to 50 g/l were recorded and thus confirms the outstanding silt storage capacity of HRF (Ref. 5).

Fig. 3:
Filter Resistance Development for Different SSF in Tanzania



3.5 Laboratory investigations at IRCWD

Since 1982 IRCWD has been investigating HRF at EAWAG's laboratories. The great experience of Dr Markus Boller of EAWAG contributed significantly to the experimental set-up and the mathematical modelling procedure. Numerous investigations of rapid multi-media filtration based on particle size measurements (Ref. 6) could be transferred to the application of HRF. IRCWD's investigations, which were funded by the Swiss Development Cooperation (SDC), studied the mechanism of HRF and elaborated detailed design information. Sophisticated equipment such as a Coulter Counter for the determination of size and number of suspended solids was available for this investigation.

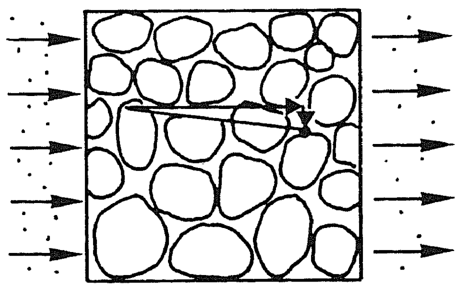
The filtration tests were carried out with a model suspension of kaolin. Kaolin is a clay mineral commonly found in tropical weathered soils. The clay particles used for the filtration tests were smaller than 20 μm and of an average size of about 1.75 μm to simulate a suspension of extremely fine particles. Pre-settled river waters usually exhibit similar fractions of particulate matter.

Transparent tubes and filter channels allowed observation of the mechanisms governing HRF. It became obvious that the predominant process in HRF is sedimentation. The horizontal movement of the suspension through the pore system of the filter is combined with a gravitational downward drift of the particles. The solids settle on top of the media grains and form loose agglomerates of several mm height. The shape of these small heaps is controlled by their slope stability. Once the deposits exceed this stability, small lumps of settled matter will move downwards within the coarse filter media, but will be prevented if filter material of less than 4 mm is used. This process presents great advantages since the retention capacity in the upper part of the filter is restored to a certain degree. At the same time, the filter bed will be gradually filled from bottom to top with retained matter. This mechanism endows the HRF with great silt storage capacities and consequently long filter runs. Fig. 4 schematises the different HRF mechanisms.

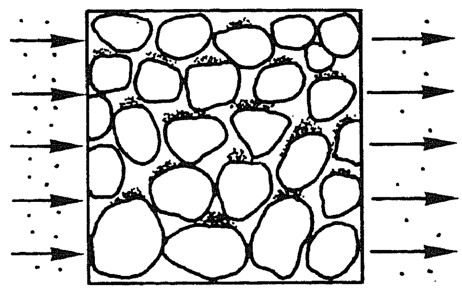
In order to determine the influence of different design parameters, (i.e. size and type of filter medium, filter length, filtration rate and filter load) on the filter efficiency and headloss, numerous parameter tests were conducted with filter cells of 10 to 30 cm diameter and 20 to 40 cm length depending on grain size. Particle counts of the suspended matter gave very accurate information on the filter efficiency under different conditions. The data obtained from the filtration tests show a distinct pattern which will be exemplified in four graphs.

Fig. 5 indicates the dependency of the initial specific filter efficiency η_i per filter length as a function of particle size d_p of the suspended matter (kaolin) in the water and filter grain size d_g (gravel of quartz) at 1 m/h filtration rate. The graphs clearly illustrate higher filter efficiencies for coarser kaolin particles and finer filter material. Filter efficiency decreases with filtration time on account of progressive filter load σ (i.e. the mass of retained matter per filter volume). The dependency of total filter efficiency η_{tot} (including all particle fractions)

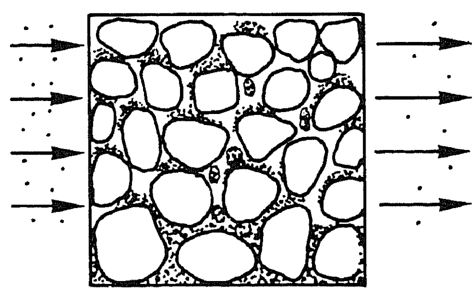
Fig. 4:
Mechanisms of Horizontal-flow Roughing Filtration



HRF acts as a multistore sedimentation tank



Accumulation of solids on the upper collector surface



Drift of separated solids to the filter bottom

Fig. 5:
Correlation Between Filter Efficiency η_i, Particle Size d_p and Filter Material of Different Sizes d_g

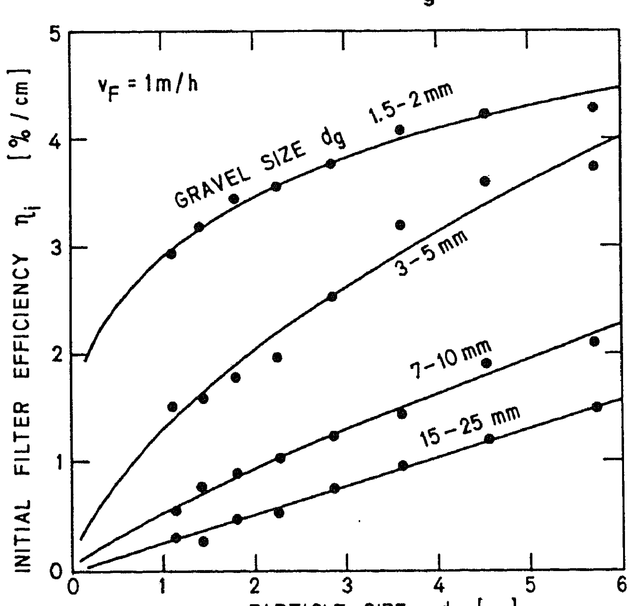
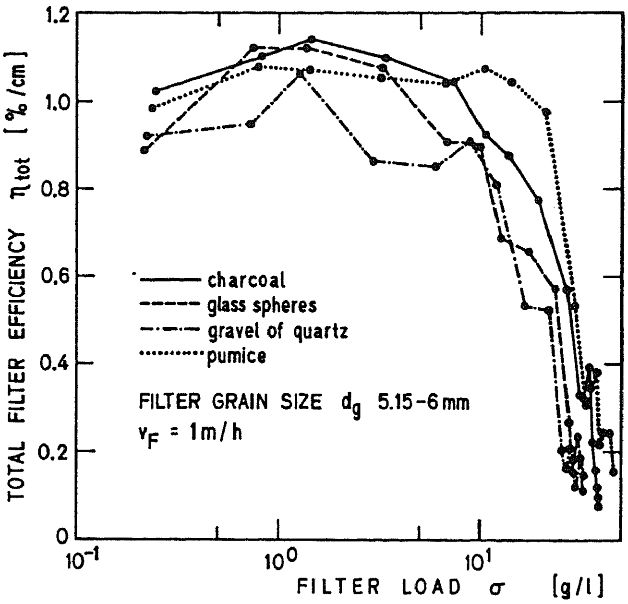
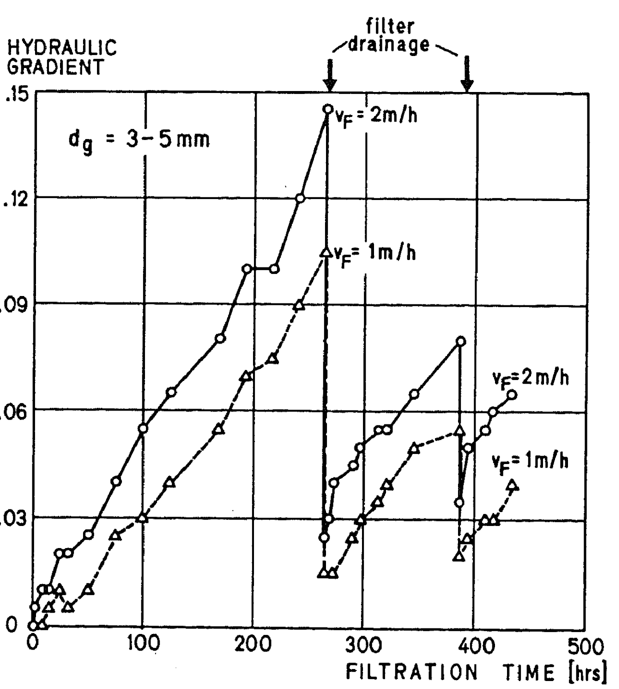


Fig. 6:
Filter Efficiency η_{tot} in Correlation to Filter Load σ and Different Filter Material



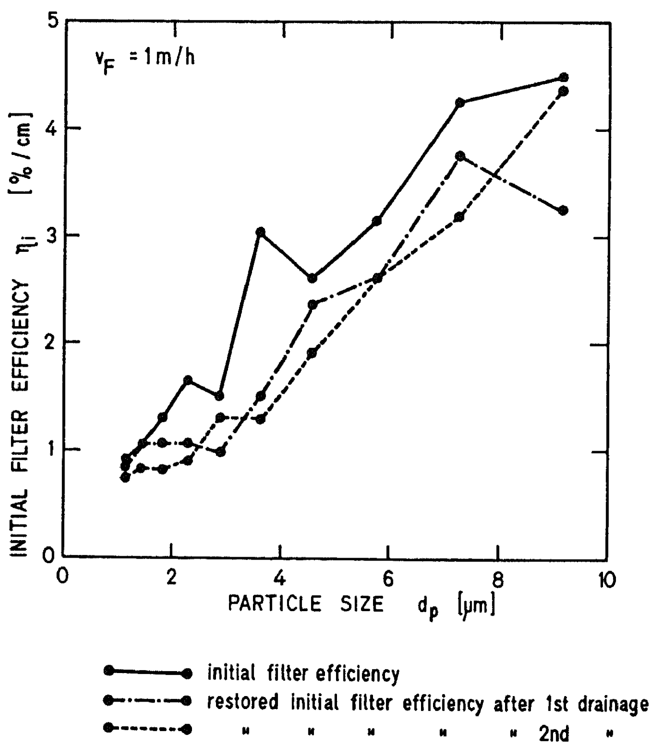
and filter load is graphed in Fig. 6 for different filter materials. Glass spheres, quartz, pumice and charcoal possess very different surface characteristics. However, under the tested conditions all four filter media behave similarly with respect to filter efficiency and filter load. This observation is of great value since any type of locally available gravel either found in a river bed or gained from a quarry can be used. Gravel might even be replaced by any other inert material like broken burnt bricks. The graphs in Figs. 7 and 8 illustrate another phenomenon observed during the filtration tests, namely regeneration of the filter efficiency by drainage. The downward drift of the deposits can be enhanced by filter drainage. If the water table in the filter is lowered, the loose agglomerates accumulated on top of the filter grains will collapse and get flushed to the filter bottom. Besides, filter resistance which is the second decisive parameter in filter design is advantageously reduced by such a drainage procedure. Fig. 7 plots the headloss development as hydraulic gradient (pressure drop per filter length) for two different filters. After 270 hours of operation, the filters were drained and filtration reassumed. Headloss dropped significantly after this drainage and reincreased with progressive filtration time. A second drainage of the filter had the same effect. Fig. 8 shows how filter efficiency η_i was restored almost to its initial value after the two drainages. This observation is also of great practical value. Occasional HRF drainages will improve filter performance and might even flush some of the accumulated matter out of the filter and thus prolong total filter run.

Fig. 7:
Filter Resistance Development and Filter Regeneration by Drainage



A semi-empirical filtration model of HRF was developed on the basis of the results obtained from these laboratory tests. Effluent quality of the pretreated water and final filter resistance are the two main criteria in HRF design. Reduction of the suspended solids concentration on the filter is described by the actual filter efficiency as a function of filter load and filtration rate, size of filter material and composition of the suspension. However, the hydraulic gradient describing the filter resistance in the filter only depends on filtration rate, size of filter material and filter load. Both parameters are described by a set of potential and exponential equations.

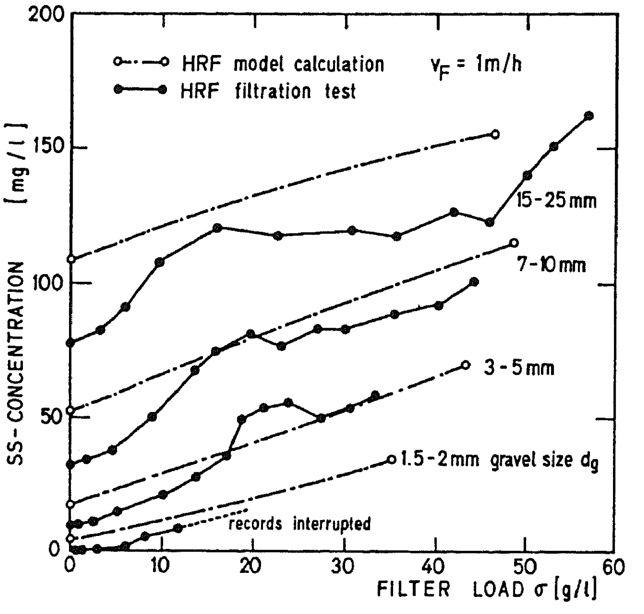
Fig. 8:
Initial and Restored Filter Efficiencies by Drainage as a Function of Particle Size d_p



The developed filtration model can be used to simulate HRF runs. With the help of model calculations, the number of filtration tests can be limited and the lay-out economically optimised. A scientific paper describing the filtration model in detail is in preparation and will be published in due course (Ref. 7).

Filtration tests with a semi-technical pilot plant were carried out in order to verify the elaborated mathematical model. Four different gravel fractions were filled in three channels, each 4 m long and of a 0.2 x 0.5 m cross section. A parallel test was run at 0.5, 1 and 2 m/h filtration rates, whereby the qualitative and hydraulic gradients were carefully recorded. A fairly good correlation was observed between model calculation and actual performance of the filter. Fig. 9 illustrates this good agreement for the HRF run at 1 m/h.

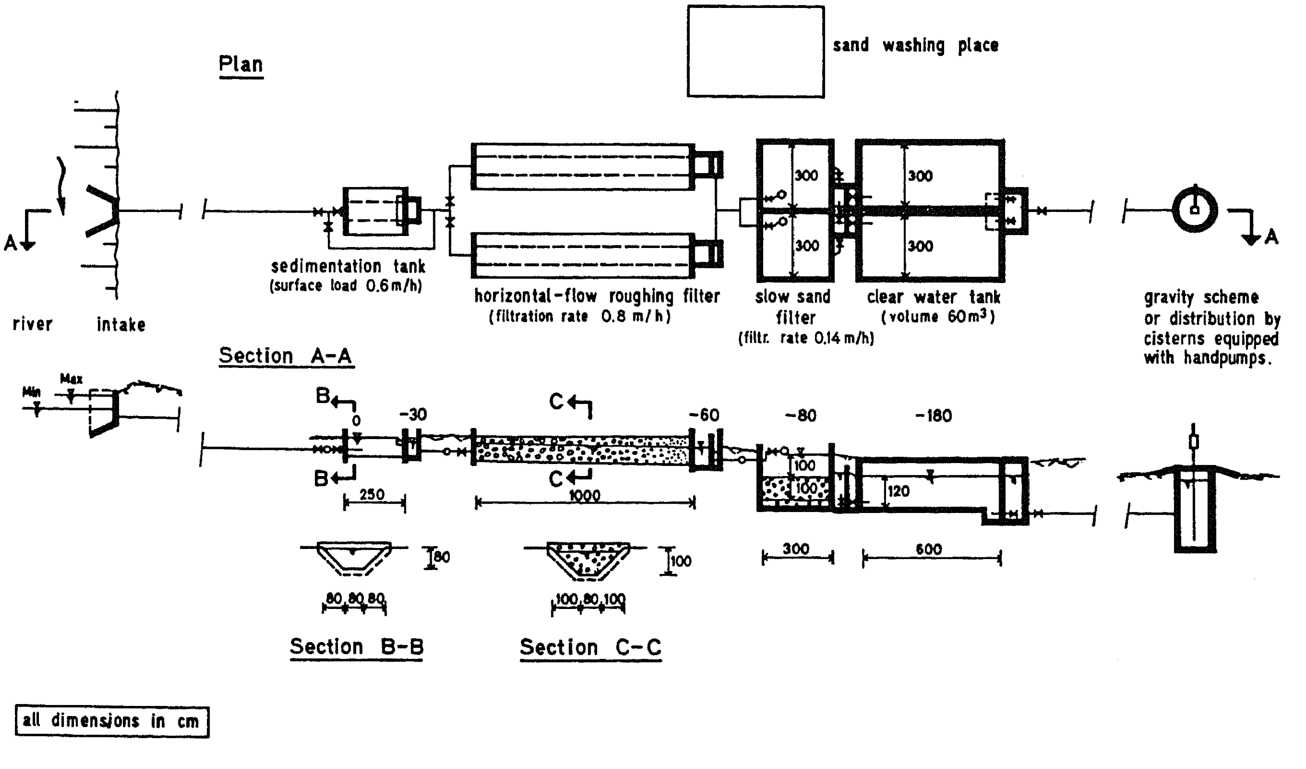
Fig. 9:
Calculated and Tested Filter Performance in Correlation to Filter Load σ



4. Design example

Fig. 10 illustrates a possible lay-out for a water treatment plant of 60 m^3/d capacity. The plant consists of a surface intake, a small sedimentation tank for the separation of coarse material, two HRF for the removal of suspended solids, two SSF for the reduction of organic matter and bacteria and two storage tanks to balance the daily fluctuation of the water demand. A remarkable fact is the relatively small size of the plant. About 20 litres of gravel for HRF and 10 litres of sand for SSF are necessary in order to supply each consumer with clean and hygienically safe water. Also worthy of note is its low energy consumption. Due to small flow velocities, the total headloss of the plant amounts to approx. 2 m. Hence, gravity flow can easily be achieved and pumping avoided. Distribution will be realised either by a gravity scheme if topography is appropriate and funds available or, as an alternative, by cisterns equipped with handpumps, thereby making the total scheme independent of any foreign chemical or energy input.

Fig. 10:
Lay-out of Water Treatment Plant for 60 m^3/d (2000 people at 30 l/c-d)



5. Conclusion

The construction, operation and maintenance simplicity and self-reliance of the filter combination HRF and SSF make this treatment technology suitable for application in rural and small urban water supplies in developing countries. The process has proven its viability under laboratory, field and practical conditions. Pretreatment of turbid water with HRF will solve operational problems experienced with so many SSF. Hence, this filter type will play a major role in the rehabilitation of water treatment plants using SSF, and will commonly enhance a broader implementation of SSF. Once tested under local conditions and introduced through demonstration schemes, this technology is reproducible with the use of local resources only. HRF combined with SSF will therefore have a potential future in the water technology of developing countries.

6. Call for cooperation

Being convinced of the implementation potential of the described treatment method, IRCWD should like to further the application of this technology. Therefore, two discussion papers on this subject will be presented at the IWSA Congress in Monastir, Tunesia on 29 October to 2 November 1984. Furthermore, IRCWD has just signed a contract with the Swiss Development Cooperation (SDC) which will be co-financing this technology in several developing countries.

Our call for cooperation to institutions involved in water treatment in developing countries is threefold. Firstly, IRCWD is grateful for any information concerning good or bad experiences with SSF. Secondly, we are willing to offer our technical advice with reference to HRF. And finally, IRCWD is seeking the cooperation of authorities in developing countries, development agencies and research institutes interested in applying HRF as pretreatment to SSF. Special attention shall be given to local institutions and national development agencies disposed to cooperate with regard to the construction (demonstration schemes with a daily capacity of 30 to 100 m^3/d are of most appropriate size), training and monitoring of HRF and SSF projects.

Comments and information on HRF and SSF should be sent to the author of this article. Any cooperation request outlining the actual local situation and planned activities in the field of water treatment should be addressed to the Manager of IRCWD.

References:

1. Slow Sand Filtration for Community Water Supply in Developing Countries, A Design and Construction Manual, Technical Paper Series 11, IRC (1978).

2. Horizontal-Flow Coarse-Material Prefiltration, Research Report No. 70, N.C. Thanh and E.A.R. Ouano, AIT (1977).

3. Functional Design of Water Supply for Rural Communities, N.C. Thanh, IDRC Research Award Report (1978).

4. Monitoring and Evaluation of Village Demonstration Plants, AIT (1981).

5. Slow Sand Filter Research Project, Reports 1—3, M. Wegelin and S. Mbwette, UDSM (1980, 1980, 1982).

6. Optimization of Design Variables for Tertiary Contact Filtration, M. Boller, IWSA Congress, Zurich, Switzerland (1982).

7. Particle Removal by Horizontal-flow Roughing Filtration, Aqua (to be published.)

New Publications

Human Waste Management for Low-Income Settlements, Seminar Report: Volume I, January 1983, 162 pages. The international seminar was held in Bangkok, Thailand, 16—22 January 1983. The report was published by the Environmental Sanitation Information Center, Asian Institute of Technology, P.O. Box 2754, Bangkok, Thailand 10501, ISBN 974-8202-12-7.

Volume I contains the seminar reports, details on the participation and organisation, ten selected papers, the report by the Organising Committee, and abstracts of all the other papers. Volume II contains the remaining papers.

This third international seminar in the field of human settlements planning was organised jointly by:
- The National Housing Authority (NHA) of Thailand
- The Asian Institute of Technology (AIT), Bangkok
- The Institute for Housing Studies — BIE of Rotterdam, The Netherlands.

The main emphasis of the forty-five papers presented and the reports and recommendations of the four workshops is placed on both technology and implementation of low-cost sanitation. It also discusses sociological and organisational factors in human waste management.

Copies are available from: ENSIC of AIT, Bangkok, Thailand. It is also possible to order reprints of the individual papers at charges on a non-profit no-loss basis.

Field Testing of Water in Developing Countries by **Len G. Hutton,** July 1983, 125 pages. This book was published by the Water Research Centre (WRC), England.

In his report Len G. Hutton of the Water and Waste Engineering for Developing Countries Group (WEDC) of Loughborough University of Technology, England, places particular emphasis in reviewing field methods for testing water quality, bacteriological techniques, suitable equipment and the approximate cost and sources of material in developing countries.

This book will be of use to engineers, scientists (chemists, geologists and bacteriologists) and laboratory technicians testing quality of water sources and treated water.

Orders can be placed with: The Water Research Centre, Medmenham Laboratory, Henley Road, Medmenham, P.O. Box 16, Marlow, Bucks SL7 2 HD, England. ISBN 0-902156-06-3. Price per copy: £ 9.50.

Who puts the water in the taps? Community participation in Third World drinking water, sanitation and health by **Sumi Krishna Chauhan et al.,** 1983, 92 pages. This paperback is an Earthscan publication.

It was written by six Third World journalists and contains eight case studies: three each from Asia and Africa, and two from Latin America. Five of them – from China, India, Pakistan, Ghana and Mexico – are based on independent field investigations by local journalists. The other three accounts, from Guinea-Bissau, Malawi and Brazil, are derived from publications. Sumi Krishna Chauhan, deputy editor of Earthscan and her collaborators have produced a kaleidoscope of Third World reality on water and sanitation motivators around the world. The focus is on the persons (health and community workers, technicians, or traditional leaders in villages or shanty towns), who may be key agents in the development process.
This publication is available from: Earthscan, 10 Percy Street, London W1P ODR, England or from Earthscan Washington Bureau, 1319 F Street NW, Washington, D.C. 20004, USA. ISBN 0-905347-47-1.

Rural Ventilated Improved Pit Latrines: A Field Manual for Botswana by **John van Nostrand** and **James G. Wilson,** TAG Technical Note No. 8, November 1983, 61 pages.

This paper is one of a series of informal Technical Notes prepared by the Technical Advisory Group on various aspects of water supply and sanitation programmes in developing countries.
It has been specifically prepared for Village Sanitation Assistants (VSAs) and village householders who, as part of Botswana's national rural sanitation programme, are working together in the construction of rural ventilated improved pit (BOTVIP) latrines. The manual sets out overall design principles, several optional designs, current construction procedures and some maintenance guidelines. It also contains an extensive number of construction illustrations and technical drawings.

A Setswana translation is being prepared by the Department of Non-Formal Education at the Ministry of Education in Gaborne, Botswana.

Copies are available from: International Bank for Reconstruction and Development, The World Bank, 1818 H Street, N.W., Washington, D.C. 20433, USA.

Handbook for District Sanitation Coordinators by **Kebadire Basaako et al.,** edited by **John van Nostrand,** TAG Technical Note No. 9, December 1983, 122 pages.

This handbook is written for District Sanitation Coordinators (DSCs) who are in charge of designing and implementing District Sanitation Programmes in Botswana.

Botswana's rural sanitation programme is derived to a great extent from the Pilot Project implemented between 1980 and 1982. This handbook is therefore largely based on the experience of this Pilot Project.

A historical outline of the project is presented in the first sections, followed by a step-by-step description of those components of the District Sanitation Programme for which the DSCs will be either directly or indirectly responsible.
In other words, the handbook is composed of the Pilot Project team's recommendations to the DSCs on how best to implement the District Sanitation Programme.

Reprints of this handbook can be obtained from: International Bank for Reconstruction and Development, The World Bank, 1818 H Street, N.W., Washington, D.C. 20433, USA.

Septic Tanks and Aqua-privies from Ferrocement by **S.B. Watt,** March 1984, 98 pages. This handbook was issued by the Intermediate Technology Publications, the publishing arm of the Intermediate Technology Development Group (ITDG), U.K.

This book is a contribution to the steadily increasing literature on low-cost sanitation. Although the ferrocement septic tank described is not in itself a low-cost option for on-site waste disposal, the techniques and principles behind the design and construction work will be readily applicable to less expensive options, such as the aqua-privy.

The publication is written for public health engineers, planners and field workers engaged in improving sanitation, and the material has been presented in simple, non-technical language. The book is divided into four chapters. Chapter 1 describes the potential of ferrocement as a construction material, and the problems of design in septic tank and aqua-privy systems. In Chapter 2 the various technical options in low-cost sanitation are contrasted and compared. Chapter 3 gives details of how septic tank and aqua-privy waste treatment and soil disposal systems are designed and constructed, and Chapter 4 gives step by step construction details of a ferrocement septic tank built for the commercial market.

Ferrocement is a proven, low-cost, less capital-intensive structural material. The design and construction methods given in this handbook will, it is hoped, indicate the potential of the material for sanitation development.

Copies are available from: IT Publications Ltd., 9 King Street, London WC2E 8HN, U.K. ISBN 0-903031-95-7. Price per copy: £ 4.95.

Guidelines for Drinking-Water Quality, Volume 1, Recommendations, World Health Organization, Geneva, Switzerland, 1984, 130 pages.

These guidelines have been developed by WHO to describe the quality of water that is suitable for drinking purposes under all circumstances. It is intended that these guidelines should be applied in developing national standards not only for community piped-water supplies but also for all water used for drinking purposes, including that obtained from community standpipes and wells and drinking-water distributed by tankers or in bottles. The guidelines can also serve as a basis for developing standards for water supplies serving transient populations, as these have been implicated in a number of epidemics of waterborne diseases.

It must be emphasized that the levels for water constituents and contaminants that are recommended in the guidelines are not standards in themselves. In order to define standards, it is necessary to consider these recommendations in the context of prevailing environmental, social, economic, and cultural conditions.

These guidelines are intended to supersede both the European (1970) and International (1971) Standards for Drinking-Water which have been in existence for over a decade.

Although the main purpose of these guidelines is to provide a basis for the development of standards, the information given may also be of assistance in developing alternative control procedures where the implementation of drinking-water standards is not feasible. For example, the existence of adequate codes of practice for the installation and operation of water treatment plants and water supply and storage systems, and for household plumbing may promote safer drinking-water supplies by increasing the reliability of the service, avoiding the use of undesirable materials (e.g. lead pipes exposed to plumbo-corrosive water), and by simplifying repair and maintenance.

This booklet may be obtained from: The World Health Organization, Distribution and Sales Services, 1211 Geneva 27, Switzerland. Special terms for developing countries are obtainable on application to the WHO Programme Coordinators or WHO Regional Offices. Orders from other countries where sales agents have not yet been appointed may also be sent to the Geneva address, but must be paid for in pounds sterling, US dollars, or Swiss francs. ISBN 92-4-154168-7. Price per copy: Sfr. 17.–.

Solid Waste Management in Developing Countries by **A.D. Bhide** and **B.B. Sundaresan,** of the National Environmental Engineering Research Institute, Nagpur, India, April 1983, 222 pages. The present volume is a INSDOC State-of-the-Art Report Series No. 2.

The present volume, which is the second in the series, deals with the basic principles involved in management of solid wastes highlighting indigenous solutions appropriate to the conditions in developing countries. Model design and cost calculations are presented to help the designers.
Some of the constituents of solid wastes can be recycled and reused, resulting in overall economy. This has been stressed as a common theme throughout this book. Special emphasis has been given to legislation, planning and management aspects which are essential to ensure an effective system.

A bibliography of 86 references and a glossary of terms relating to solid wastes are appended to the report. Other annexes relate to collection and analysis of refuse samples, preparation of refuse samples for microscopic analysis and municipal Acts of Bombay, Calcutta, Sri Lanka and Singapore.

This report will serve as a practical tool for the effective and economic management of solid wastes in developing countries.

Copies are available from: Indian National Scientific Documentation Centre (INSDOC), 14, Satsang Vihar Marg, Off S.J.S. Sansanwal Marg, Special Institutional Area, New Delhi-110 067. Price per copy: India - Rs. 40.00 or $ 12.50.

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