International Journal of Physical Sciences Vol. 4 (9), pp. 455-463, September, 2009
Available online at http://www.academicjournals.org/ijps
ISSN 1992 - 1950 © 2009 Academic Journals

Review

Roughing filter for water pre-treatment technology in developing countries: A review

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Accepted 27 July, 2009

Roughing filtration can be considered as a major pre-treatment process for wastewater, since they efficiently separate fine solids particles over prolonged periods without addition of chemicals. This review article summarizes and evaluates modifications to roughing filtration technology, which may address these limitations without compromising the simplicity of the treatment process. Successful modifications includes broken burnt bricks, charcoal and coconut fibre as filter media. The paper also reviews the design concept and process capabilities for roughing filter and it also discusses recent innovations in roughing filter design that now enable this technology to be applied more widely than would have been appropriate 2 decades ago. Achieved results in this study shows that roughing filtration may be considered as efficient pretreatment process incase surface water is used as water supply.

Key words: Roughing filter, sedimentation, absorption, turbidity.

INTRODUCTION

Surface water is sometimes the only available safe water source for rural homeowners. Typical problems encountered can be caused by high suspended solids, turbidity, coliform bacteria, agricultural runoff (Blackburn, 1997). Previous studies have shown roughing filtration to be an effective and reliable method for removing suspended solids, turbidity and coliform bacteria (Clarke et al., 1996; Collins, 1994; Galvis et al., 1998; Wegelin, 1986). For suspensions with particulates that do not readily settle, roughing filtration provides superior treatment to basic sedimentation methods (Wegelin, 1996) and represents an attractive alternative to more costly conventional coagulation methods.

Roughing filters are primarily used to separate fine solids from the water that are only partly or not retained at all by stilling basin or sedimentation tanks. Roughing filters mainly acts as physical filters and reduce the solid mass. However, the large filter surface area available for sedimentation and relatively small filtration rates also supports absorption as well as chemical and biological processes.

Therefore besides solid matter separation, roughing filters also partly improve the bacteriological water quality and to a minor extent, change some other water quality parameters such as colour or amount of dissolved organic matter (Wegelin, 1996). Roughing filters are classified as deep-bed filters, whereby proper filter design promotes particle removal throughout the depth of the filter bed, maximizing the capacity of the filter to store removed solids. Particle removal efficiency in roughing filters is dependent on filter design, particulate and water quality parameters (Boller, 1993; Collins, 1994; Wegelin, 1986).

TRADITIONAL DESIGN OF ROUGHING FILTERS

The natural water treatment potential was adopted long before chemical water treatment methods, such as chlorination and flocculation, were discovered and applied. Gravel and sand used as filter media are key components in natural treatment processes. Although sand was able to maintain its important role since the development of the first slow sand filters at the beginning of the last century, the use of roughing filters was successively replaced by chemical water treatment processes (Wegelin, 1986). However, a few examples presented hereafter document that the roughing filter technology is

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an old water treatment process used in the past and rediscovered in recent years.

Numerous castles and forts were constructed in Europe during the middle ages. They were often located at strategically important points, difficult to conquer and also to supply with water. A good example is the former castle of Hohentrins located on top of a steep rocky reef in the Swiss Alpine valley of the river Rhine. During periods of war, the people who sought protection in this castle depended on rainwater collected in the yard and stored in a cistern. In this extensively used area, it was, however, not possible to avoid water pollution caused by man and animal. Therefore, in order to treat the water, a gravel pack was installed around the inlet of the cistern. This is probably 1 of the first roughing filters used to treat surface water (Wegelin, 1996).

In 1804, John Gibb constructed the first water filtration plant for a public water supply at Paisley in Scotland. In order to pretreat the muddy river water, John Gibb designed and constructed an intake filter described as follows: "Water from the River Cart flowed to a pump well through a roughing filter about 75 feet long, composed of "chipped" freestone, of smaller size near the well than at the upper end. This stone was placed in a trench about 8 feet wide and 4 feet deep, covered with 'Russian mats" over which the ground was leveled". The pretreated raw water was then lifted by a steam engine-driven pump to a place 16 feet higher than the river from where it flowed by gravity to the water treatment plant. This installation consisted of 3 concentric rings each 6 feet wide and arranged around a central clear water tank measuring 23.5 feet in diameter. The water flowed in horizontal direction from the outer ring, which was used as settling basin; through the 2 other rings towards the centre into the clear water tank. The 2 inner rings contained coarse and very fine gravel or sand as filter material respectively. John Gibb applied, already then, the multi-stage treatment approach; that is, the intake filter, the settling basin and the gravel filter were used as pretreatment processes prior to sand filtration.

RECENT DESIGN CONCEPT

With the renewed interest in roughing filter has come fresh thinking on design concepts related to plant layout, access to filter performance, monitoring and kinds of materials to use for filter media. Wegelin design can simplify construction of a filter and can make the design job easier. Now the conceptual filter theory for evaluating the efficiency of the filter is still based on the filtration theory described by Wegelin (1996). When a particle in the water passes through a gravel bed filled up with gravel there is a chance to escape the particle either on the left side or on the right side or a chance to settle at the surface of the gravel. Hence the probability of chance of the success of removal and the failure is $^1/_3$ and $^2/_3$.

According to Fick's law the filter efficiency can be expressed by the filter coefficient or,

$$\frac{dc}{dx} = -\lambda c \quad (1)$$

Where;
c = Solid concentration.
x = Filter depth.
λ = Filter coefficient or coefficient of proportionality

From the above equation it can be stated that the removal of the suspended particles is proportional to the concentration or the particles present in the water.

The total length of the filter can be described as the number of parallel plates and act as a multistage reactor so the performance of the HRF can be ascertained on the basis of the results obtained from the small filter cells. The total suspended solid concentration after a length of Δx of the filter cell can be expressed,

$$c_{outlet} = \Sigma^{C}{}_{inlet} e^{-\lambda i \Delta x} \quad (2)$$

Where;
λ_i = Filter efficiency of each filter cell.
Δx = Length of experimental filter cell.
c_{inlet} and c_{outlet} = Concentration of particles in the inlet & outlet of the filter.

It is to be stated that after evaluating the filter depth (length) and the filter coefficient and the Suspended Solids concentration, the performance efficiency of the filter can be predicted.

According to Wegelin (1996), the effluent quantity for the n number of compartments is given by:

$$Ce = C_0{}^* E_1{}^* \ E2^* \ E3^* \ E4^*. \ .... \ ...En \quad (3)$$

Where;
C_0 = Concentration of the HRF influent.
Ce = Concentration of the HRF effluent.
E_1, E_2, E_3, E_4. ....E_n = Filtration efficiency for the each compartment (1, 2, 3 respectively).

The basic expression for the above relationship is expressed by:

$$Ce = Coe^{-\ddot{e}L} \quad (4)$$

Where:
$\ddot{e}$ = Coefficient of filtration
L = Length of the filter.

The Filter efficiency is given by:

$$E = Ce/C_0 = e^{-\ddot{e}L}$$

$$Ce = Co^* E \quad (5)$$

E_i = Filter efficiency for (i–1, 2, 3 . . . n) compartments.

The description of the theory above showed that solid removal by filtration can be described by exponential equation.

ARTIFICIAL NEURAL NETWORK

Artificial Neural Network is a distributed information processing system that has certain characteristics that resemble with the biological neural network of the human.

The development of an artificial neural network as prescribed by ASCE (ASCE, 2000), must follow the following basic rules:

1. Information must be processed at many single elements called nodes.
2. Signals are passed between nodes through connection links and each link has an associated weight that represents its connection strength.
3. Each of the nodes applies a non-linear transformation called as activation function to its net input to determine its output signal.0.0 (Yitian and GU, 2003).The accuracy of results obtained from the network can be assessed by comparing its response with the validation set. The commonly used evaluation criteria include percentage MSE, correlation coefficient (r), coefficient of efficiency (C.E.) and Standard Deviation (STDEV).

$$\%MSE = (Tp - Op)/Tp) \times 100$$

$$r = [X\,(Tp - Tm)(Op - Om))/(Xn1(Tp - Tm)2Xn1\,(Op - Om)2)1/2]$$

$$C.E. = 1 - (Xn1\,(Tp - Op)\,2/\,Xn1\,(Tp - Tm)\,2)$$

$$STDDEV = \frac{En\,(T\,n - \bar{}\;T\,n)\,2}{n}$$

Where, *Tp* is the target value for the *p*th pattern; *Op* is the estimated value for the *p*th pattern, *Tm* and *Om* is the mean target and estimated values respectively and *n* is the total number of patterns. MSE shows the measure of the difference between target (*Tp*) and estimated (*Op*) value, *r* defines the degree of correlation between 2 variables. C.E. Criterion has the basis of standardization of the residual variance with initial variance (Nash and Sutcliffe, 1970).

In this criterion, a perfect agreement between the observed and estimated output yields an efficiency of 1. A negative efficiency represents lack of agreement and zero agreement means all the estimated value is equal to the observed mean. STDDEV is the measure of deviation of the estimated value from the target output. A perfect match between observed data and model simulations is obtained when STDDEV approaches.

TYPES OF ROUGHING FILTERS

Vertical flow roughing filters

Vertical-flow roughing filters operate either as down flow or up flow filters. They are hence either supplied by inflowing water at the filter top or at the filter bottom. The vertical flow roughing filters incorporates a simple self cleaning mechanism and occupies minimal floor space when compared to horizontal flow roughing filters.

The filter material of vertical-flow roughing filters is completely submerged. A water volume of about 10 cm depth usually covers the gravel and other local available materials like coconut fiber and broken burnt bricks. The top should be covered by a layer of coarse stones to shade the water and thus prevent algal growth often experienced in pretreated water exposed to the sun. Drainage facilities, consisting in perforated pipes or a false filter bottom system, are installed on the floor of the filter boxes. Finally, pipes or special inlet and outlet compartments are required to convey the water through the subsequent 3 filter units and they are shown in Figure 1.

Horizontal flow roughing filters

As shown in figure 1, unlimited filter length and simple layout are the main advantages of horizontal roughing filters. Horizontal roughing filters have a large silt storage capacity. Solids settle on top of the filter medium surface and grow to small heaps of loose aggregates with progressive filtration time. Part of the small heaps will drift towards the filter bottom as soon as they become unstable. This drift regenerates filter efficiency at the top and slowly silts the filter from bottom to top.

Horizontal-flow roughing filters also react less sensitively to filtration rate changes, as clusters of suspended solids will drift towards the filter bottom or be retained by the subsequent filter layers. Horizontal-flow roughing filters are thus less susceptible than vertical-flow filters to solid breakthroughs caused by flow rate changes. However, they may react more sensitively to short circuits induced by a variable raw water temperature.

ROUGHING FILTER DESIGN PARAMETERS

Filter media size

Media types commonly used in roughing filtration are quartz sands and gravels but can be replaced by any clean, insoluble and mechanically resistant material (Graham, 1988).

Previous work by Wegelin (1986) showed that the effect of surface porosity and roughness of filter media on particle removal efficiency in roughing filtration was insignificant compared to the size and shape of macropores in the filter. Rooklidge and Ketchum (2002) studied the removal efficiencies in calcite limestone, basaltic river

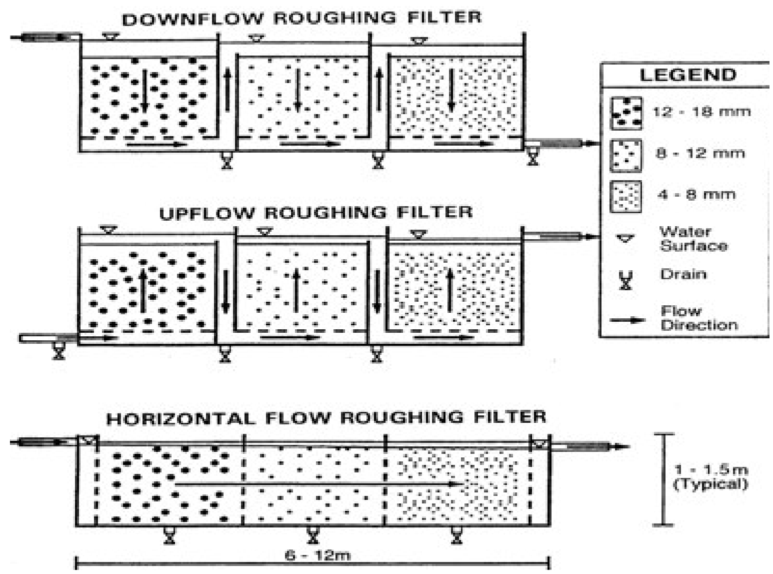

Figure 1. Diagram of horizontal, up flow and down flow roughing filters.
Source: (Wegelin, 1996).

Table 1. Different sizes of roughing filter media.

Roughing filter description	First compartment (mm)	Second compartment (mm)	Third compartment (mm)
Coarse	24-16	18-12	12-8
normal	18-12	12-8	8-4
Fine	12-8	8-4	4-2

rock, and limestone-amended basalt horizontal roughing filters and found only marginally improved efficiency (7%) for calcite amended basalt filters over unaltered filters. Improved removal efficiencies are generally correlated to smaller media sizes (Collins, 1994; Wegelin, 1986).

The use of multiple grades of filter media in a roughing filter promotes the penetration of particles throughout the filter bed and takes advantage of the large storage capacities offered by larger media and high removal efficiencies offered by small media. The size of filter media decreases successively in the direction of water flow and ideally the uniformity of filter media fractions is maximized to increase filter pore space (storage capacity) and aid in filter cleaning (Boller, 1993).

Common grades of media used in roughing filters are provided by Wegelin (1996) and shown in Table 1.

Alternative filter media

The filter material should have a large specific surface to enhance the sedimentation process taking place in the roughing filter and high porosity to allow the accumulation of the separated solids. Generally speaking, any inert, clean and insoluble material meeting the above 2 criteria can be used as filter medium. Filtration tests revealed that neither the roughness nor the shape or structure of the filter material have a great influence on filter efficiency. The following material could therefore be used as filter media:

a) Gravel from a river bed or from the ground.
b) Broken stones or rocks from a quarry.
c) Broken burnt clay bricks.
d) Plastic material either as chips or modules (e.g. used for trickling filters) may be used if the material is locally available.
e) Burnt charcoal, although there is a risk of disintegration when cleaning the filter material, it should only be considered in special cases (e.g. for removal of dissolved organic matter).
f) Coconut fibre, however, due to the risk of flavouring the water during long filter operation, it should be used with care.

Researchers like Ochieng (2006) noted that broken burnt bricks and improved agricultural waste (charcoal Maize cobs), can also be effectively used as pretreatment media

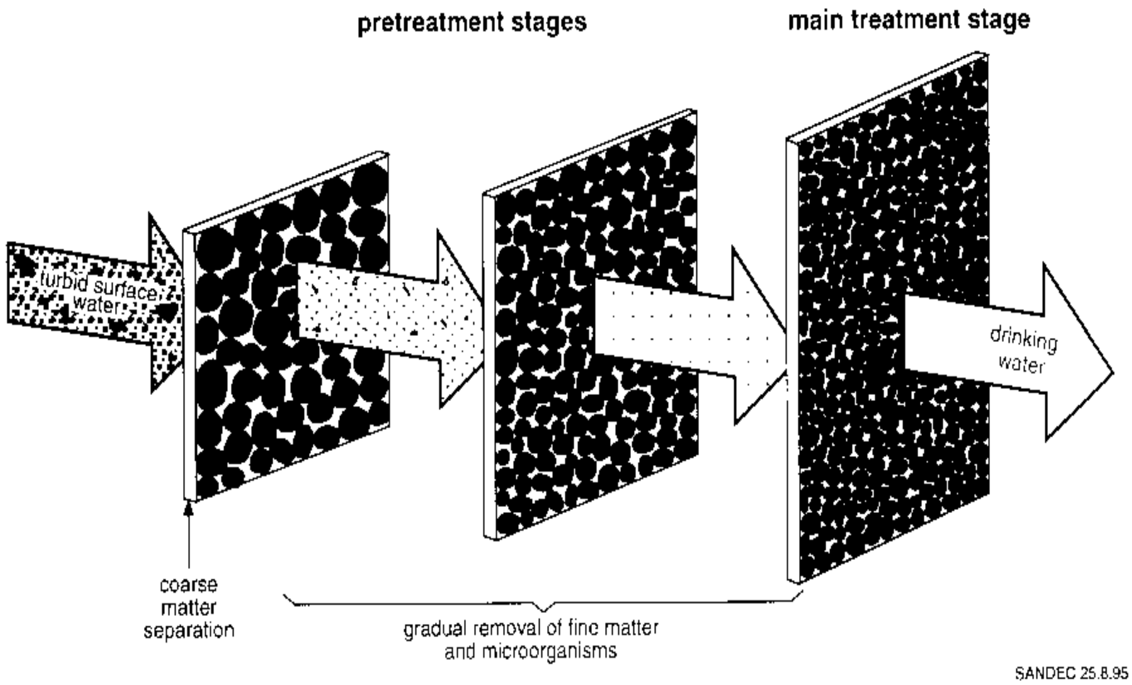

Figure 2. Shows the mechanism of roughing filters.

media and therefore could serve as alternatives where natural gravel is not readily available. It was observed that in general both broken burnt bricks and charcoal performed better than gravel. This observation could have resulted from the reason that both charcoal maize cobs and broken burnt brick have a slightly higher specific surface area and porosity respectively to enhance the sedimentation and other filtration processes compared to gravel.

Filtration rate

Filtration rate also has a significant influence on the treatment removal. Good removal in roughing filters are best achieved with low filtration rate (Boller, 1993), because low filtration rates are critical to retain particles that are gravitationally deposited to the surface of the media. While as pretreatments used for removal of iron and manganese were able to operate at filtration rates of 1.5 - 3 m/h (Hatva, 1988). Researchers like (Dastanaie, 2007) reported that horizontal flow roughing filter is capable of removing metals like iron, manganese, turbidity and colour at a filtration rate of 1.8 m/h.

Wegelin et al. (1986) found that at increased filtration rates (2 m/h), coarse particles penetrate deeper into the bed and these will cause decrease in filter efficiency. Whereas at 1 m/h there was good distribution of solids loading throughout the bed. Hendricks (1991) also suggested that normal filtration rate of horizontal roughing filters is between 0.3 and 1.5 m/h.

Filter length

Improved cumulative removal efficiencies are typically correlated to longer filter lengths (Collins, 1994; Wegelin, 1986). However, incremental removal efficiencies tend to decrease with increasing filter length due to the preferential removal of larger particles early in the filter (Wegelin, 1996). The rate of decline is dependent on filter design variables and the size and nature of particles in suspension. The use of different media sizes may allow for treatment targets to be met by a shorter filter with multiple media sizes compared with long filter packed with one media size.

MECHANISM OF ROUGHING FILTERS

As illustrated in Figure 2, water has to undergo a step to step treatment especially if it contains differently sized impurities. The first and easiest step in sound water treatment schemes is coarse solids separation. Finer particles are separated in a second pretreatment step and finally, water treatment will end with the removal or destruction of small solids and microorganisms. These different pretreatment steps will contribute to reducing the pathogenic microorganisms. The pathogens attached to the surface of suspended solids will get stranded when the solids are separated. Some of the microorganisms floating in the water might also get pushed to the surface of the treatment installations and adhere to biological films. Solid matter and microorganisms, therefore, face a multitude of treatment barriers. Since treatment efficiency of each bar-

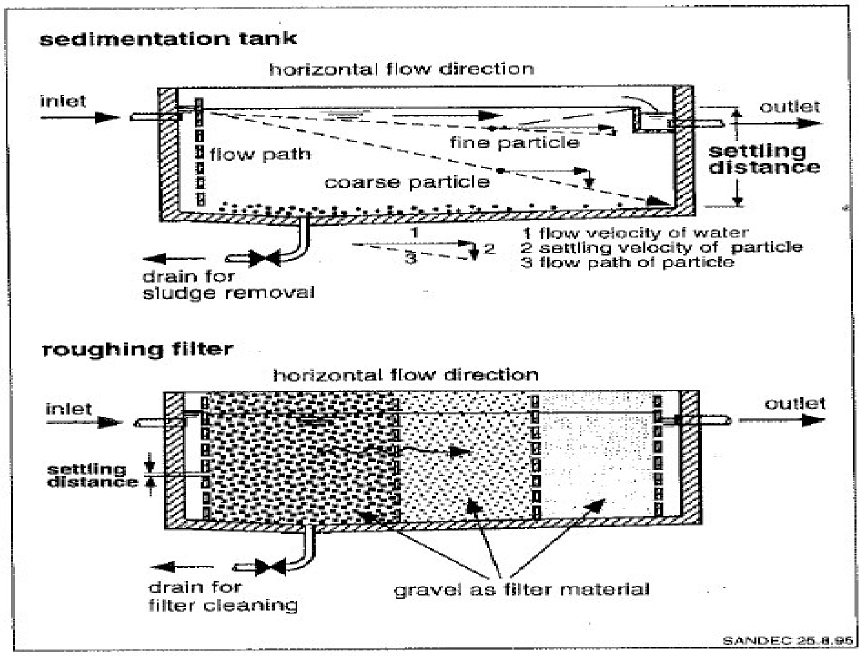

Figure 3. Solids removal in HRF (Wegelin, 1996).

of each barrier increases in the direction of flow, it becomes increasingly difficult for the impurities to pass through each subsequent treatment barrier. Removal of suspended solids in RF requires laminar flow (Galvis et al., 2006). Hydrodynamic forces that move the water through the pore system create patterns of flow retardation and acceleration that have pockets of stagnant water near the media surface allowing particles to settle and it was shown in Figure 3. A sticky organic film on the surface of the media in the pores retains the suspended solids by mass-particle attractions through the Vander Waals forces and electrostatic forces between charged particles (Wegelin, 1996).

PRACTICAL EXPERIENCE WITH ROUGHING FILTERS

Experience in Iran

A Vertical flow pilot plant was designed and run by Dastanaie (2007) at the bank of Zayandehroud River near the village of Chamkhalifeh in 2003. In order to provide required head, the pilot was installed 2 m below the elevation of river bed. Water was conducted towards the filter via a man made conduit. The filter is comprised from 3 different parts which are separated with perforated baffles. Each compartment is filled with some local sand and gravel considering a special decreasing size regime. In other words, the diameter of stuffs in the compartments is decreased from 25 - 15 mm in the first compartment to 15 - 8 mm in the second and 8 - 4 in the last one. The average height of materials in the filter is 2.5 m and water always undergoes a subsurface flow beneath the surface of the filter. In order to monitor the quality of outlet water, parameters like total suspended solids (TSS), turbidity, color and fecal coliforms as well as ions like iron and manganese are being compared between inlet and outlet water.

The comparison between the values of mentioned parameters in inlet and outlet water is illustrated in table 2. As it is shown in the figures, the overall function of the filter in removing turbidity and TSS is acceptable. Additionally, iron, manganese and color removal are also been covered to some extent.

Experience in Malaysia

A pilot plant was constructed in Malaysia by Nordin Adlan and he examines and evaluates the removals of turbidity, suspended solids and BOD and coliform organisms from wastewater using different sizes of limestone roughing filter. Results indicated that removal efficiencies depended on the size of the filter medium and applied flow rates. Turbidity, suspended solids, BOD and coliform organisms' removals were between 75 and 92%, 79 and 88%, 51 and 67% and 67 and 96%, respectively, in a combination of the 3 filter media with particle sizes between 1.91 and 16.28 mm. Removal efficiency was found to increase with slower flow rates.

Experience in Africa

Another study was investigated by Ochieng and Otieno (2004) in a pilot plant built at Moi University in Kenya using

Table 2. Removal efficiencies of the filter.

Parameters	Unit	Inlet	Outlet	Removal %
Turbidity	NTU	3.528	1.29	63.4
Colour	mg/l	0.8	0.6	20
Iron	mg/l	0.083	0.07	15.6
manganese	mg/l	0.0417	0.015	64
TSS	mg/l	18.93	1.95	89.7
Coliforms	MPN	112.6	6.74	94

broken burnt bricks and charcoal, as filter media for removal of Suspended solids and turbidity. They noted that broken burnt bricks and improved agricultural waste (charcoal Maize cobs), can also be effectively used as pretreatment media and therefore could serve as alternatives where natural gravel is not readily available. The design and sizing of the pilot plant was guided by Wegelin design criteria and a constant filtration rate of 0.75 m/h was chosen for the HRF units. It was observed that in general both broken burnt bricks and charcoal performed better than gravel. This observation could have resulted from the reason that both charcoal maize cobs and broken burnt brick have a slightly higher specific surface area and porosity respectively to enhance the sedimentation and other filtration processes compared to gravel.

Another pilot HRF was constructed and operated by Tamar Rachelle Losleben at Ghanasco Dam in Tamale, Northern region Ghana using three 7 m tubes filled with 3 sizes of granite gravel, local gravel and broken pieces of ceramic filters arranged by decreasing size. The pilot study was run for 52 days to test if HRF could reduce the high turbidity (305 NTU) to < 50 NTU to make SSF a viable option. There were a number of promising outcomes: the best performing media, the granite gravel, by removing an average 46% of the influent turbidity (filter coefficient ë = 0.002 min -1), produced an average effluent turbidity of 51 NTU which almost achieved the goal of < 50 NTU. The granite gravel, HRF removed twice as much turbidity (46%) as plain settling (25%). Overall, the granite gravel removed 76 and 84% of the influent turbidity according to the settling test and pilot HRF data respectively.

Another pilot plant was constructed by University of Zambia, Lusaka, Zambia, in collaboration with Delft University of Technology, Delft; the Netherlands have embarked on a research programme on surface water treatment. The pilot plant comprises 2 identical treatment lines each having 1 upflow roughing filter in layers (URFL) and 1 inlet controlled slow sand filter (SSF). The filter media for both URFL and SSF were obtained from natural local sources. Raw water was drawn from the Kafue River, 1 of the major rivers in Zambia. The river normally exhibits low turbidity levels during the dry season (daily averages of 3 - 30 NTU), with peaks of 50 -300 NTU occurring during the rainy season. Since the pilot plant was operational during the dry season, clay suspensions were prepared using clay from the Kafue river banks to simulate turbidity peaks.

The URFL was operated at average filtration rates of 0.4, 0.5 and 0.75 m/h, while the SSF was operated at an ave-rage rate of 0.2 m/h. The raw water and filtered waters were checked for turbidity, total suspended solids and coliform organisms. Filter resistance was also monitored by means of piezometer tubes installed at various heights of the filter. During the first trial (from March 2nd until March 31st, 1997), the URFL was operated at a filtration rate of 0.4 m/h. During this period, average turbidity removal ranged from 32-93%, with average daily influent turbidities between 1.08 - 10.67 NTU.

Experience in India

A pilot plant was constructed in the depth of water resources engineering, Jadavpur University to investigate the objectives of the research study. The structure of the plant was made up from the Fiber glass sheeting which consisted of three chambers of each 450 × 300 mm. The filter medium namely gravel was placed in the 3 separate chambers starting from the coarse size to the finer ones in the direction of flow and the whole system was operated in series. The first compartment was filled up of gravel size 15 – 10 mm having the average size 12.5 mm the second compartment consisted of average gravel size 7.5 mm and the third one of average size 2.5 mm. Each compartment was being separated by the perforated fiber glass partition to avoid mixing of the gravels of different chambers. The filter bed was provided with the under drainage system to enable flushing after a certain running period of interval for hydraulic sludge extraction by observing the filter resistance. A constant flow rate of 0.75 m/h was maintained through all the compartments by the help of a peristaltic pump. The suspended solids (SS) concentration of raw water for all the chambers at the inlet and the SS concentration at the out let was measured by the help of standard procedure describe in the Standard methods. Sampling from the investigation was done at least 3 times of week for a period of 70 days. The experiment was carried out both in low flow (dry season) and high flow (rainy season) periods during the scan of 70 days. The local pond water was used as raw water which has the concentration of suspended solids ranges from 40 to 150 mg/l. According to Weglin's design guide line this range is medium range of concentration (100 – 300) mg/l for which filtration rate is 0.75 – 10 m/h are recommended. So a constant flow 0.75 m/h was chosen in carrying out the project. E value and filter efficiency was shown in Table 3.

Experience in Sri Lanka

Jayalath (2004) in a pilot plant built in Sri Lanka found out

Table 3. Removal efficiency of the filter.

Effective size (dg) (mm)	Filtration rate (m/h)	Length of compartment (m)	E-value %	Total E –value (dec)
5	0.75	0.45	$E_1 = 21.3$	0.026
10	0.75	0.45	$E_2 = 19.6$	
15	0.75	0.45	$E_3 = 26.0$	

Table 4. Performance of roughing filters.

Reference	Filtration Rates (m/h)	Parameters	Mean percent removed (%)
Pacini(2005)	1.20	Iron and manganese	85 and 95
Dome (2000)	0.3	Algae and turbidity	95 and 90
Mahvi (2004)	1.5	Turbidity	90
Ochieng and Otieno (2004)	0.75	Turbidity and algae	90 and 95
Dastanaie (2007)	1.8	Turbidity, TSS and Coliforms	63.4, 89 and 94
Jayalath (1994)	1.5	colour and turbidity	50 and 60
Rabindra (2008)	1.0	TSS and turbidity	95 and 95
Mukhopadhay (2008)	0.75	Turbidity	75

that there is a considerable reduction in Synedra population (80 – 87% in terms of cell count) as well as colour and turbidity (50 – 60%). Highest percentage removal was obtained form the filtration velocities below 1.5 m/h for color and turbidity and below 2 m/h for algae removal. Field-scale experiments show that filter length does not provide a significant effect on the percentage reduction of algae count, color and turbidity. Horizontal flow velocity was maintained at 1.0 – 2.5 m/h. As the flow velocity increased up to 4.5 m/h, algae removal reduced to 70% while color and turbidity to 40%. It was observed in Table 4 that Paciani (2005) used 1.20 m/h filtration rate for his pilot plant experiment. He achieved 85 and 90% respectively on iron and manganese reduction in the plant. Some also used 0.3 m/h filtration rate for his experience and achieved 95 and 90% respectively for algae and turbidity removal in the waste water. Experiences from researchers are shown in Table 4.

DISCUSSION

Factors affecting roughing filter performance

The disadvantage of RF is low hydraulic load. The only way to provide sufficient treated water to meet a high drinking water demand would be to build a larger RF unit (Boller, 1993). The filtration rate (m/h) depends largely on the type of filter, the water characteristics, desired turbidity reduction, Variations in the filter media (porosity), each filter medium's proportion, the number of filter fractions and height and width of filter bed area (m^2) dictate filtration and optimize the removal of suspended matter. The filter media size (mm) and type (gravel and broken clay) is also an important consideration. The most influential factor for turbidity removal efficiency in the raw water is particle sizes and distribution.

Filter efficiency depends on the concentration of suspended solids. The $^1/_3$ and $^2/_3$ Filter theory explains how each layer removes about $^1/_3$ of the particles letting the other $^2/_3$ flow to the next layer (Wegelin, 1996). This continues at each layer, because there is a greater concentration of particles at the first layer, more particles are removed than in latter layers. Intermittent flow operation can greatly decrease the particle removal efficiency because it is possible that the biofilm around the coarse media might have dried and lost its sticky properties (Galvis, 2006).

High sludge storage space can be advantageous in lengthening filter runs but becomes problematic when the filter finally needs to be cleaned. Its buffering capacity to manage fluctuating solid concentrations exists because the large pore spaces allow considerable amounts of solids to be stored at very low head loss (Boller, 1993). Periodic drainage through perforated or corrugated pipe may be able to improve the filter run time between cleanings and needs to be further developed (Boller, 1993). Scraping of the top layer of biofilm on a weekly basis could also improve the filter run time. Fully unpacking the media and cleaning it is 1 of the biggest drawbacks of the RF even when the media is readily accessible as it is in HRF.

Advantages of roughing filters over conventional methods

Conventional system is quite demanding in chemical use, energy input and mechanical parts as well as skilled manpower that are often unavailable, especially in rural areas of developing countries like Tanzania, Kenya and Sri Lanka. But roughing filters does not require chemical use, energy input and mechanical parts. Conventional methods demand high operating costs.

Disadvantages of roughing filters over conventional methods

Colour removal is fair to poor and in some cases it requires a large area of land for effective treatment. It can handle only relatively low strength wastes compared to conventional methods. It also can handle only very low organic loads compared to conventional treatment methods such as activated sludge process.

Conclusion

With regards to water crises in Africa and throughout the world, a decline in rainfall and drought threat throughout numerous countries and considering the point that the majority of easily accessed water resources are surface water resources, by applying self reliant processes, which are economic important, the mentioned process such as roughing filtration, must be studied to provide healthy refreshing drinking water to developing countries like Tanzania. Considering removal efficiency for total suspended solids, manganese, turbidity, colour, algae and iron respectively, this system has shown convincible results. Achieved results in previous study shows that roughing filtration may be considered as efficient pretreatment process incase surface water is used as water supply for treatment. But this can be achieved, if applied to appropriate source water and when designed and operated properly. Ochieng and Otieno, 2004 found out that in the high peak period, the suspended solids, even though not to the design level, could have been high enough to promote sedimentation and other filtration processes such as adsorption to register high removal efficiency. In the low-peak period, a lower reduction percentage for all the filters was recorded. This observation could be attributed to the fact that low suspended solids in the dry season could have possibly reduced the sedimentation process due to a possible increase in the colloidal stability and hence less particle interaction.

ACKNOWLEDGEMENT

The authors would like to thank Tshwane University of Technology for offering the principal author scholarship to undertake his studies for a Masters degree.

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