CHAPTER 1

INTRODUCTION

1.1 General

Drinking water is supplied via surface and groundwater resources all around the world. Countries which are depended on surface water resources as drinking water supply are always encountered with high amounts of colloidal, dissolved and suspended solids in the bulk of raw water. Accordingly, total costs of conventional drinking water treatment process including initial, operation and maintenance costs have been always under debate in these regions, specially, in developing countries where supplying required chemicals as well as expert man power are posed as major controversial financial problem.

It is more highlighted when we are dealing with small scale societies with low population where implementation of a multipart treatment system is not economically justified. Having the capability of simultaneous sedimentation and filtration, horizontal-flow rough filtration is an applicable alternative for supplying drinking water. On the contrary to slow and even rapid sand filters, horizontal-flow rough filters (HRFs) are not sensitive to high amount of turbidity and are able to function more than two months without the requirement of being backwashed. (Dastanaie, et al., 2007)

Many tropical rivers show a wide fluctuation in suspended solids content and other water quality characteristics water treatment plant drawing raw water from such rivers are facing growing problems in providing desired treated water quality as well as quantity. This problem is compounded for the towns and small cities in developing countries due to their limited financial resources (Wegelin and Schertenleib, 1993). The horizontal – flow roughing filter (HRF) is claimed to have the advantage of being able to tackle relatively high raw water turbidity, whilst at the same time offering long filter run time and a simple technology (Galvis et al, 1993).

Water filtration is a process of separating suspended or colloidal impurities from water by passage through a porous medium , usually a bed of sand or other medium. Water fills the pores (open spaces) between a sand particles and the impurities are left behind, either clogged in the open spaces or attached to the sand itself.

1.2 Problem statement

Pollutants and suspended solid in stream water are hazardous to human. Pollutants and suspended solid can produce carcinogenesis among other undesirable effects that affect the human health. An attractive alternative of low cost sorbents for pollutants and solid removal treatment in water to replace high cost sorbent is needed. Horizontal roughing filter could be one of the easier method to remove pollutants and solid in stream water. Previous studies showed that media size and flow rate play an important roles in suspended solid removal efficiency in horizontal roughing filter. So these two parameters ware manipulated to study the effect of different size of media and flow rates on removal efficiency.

1.3 Research objectives

- To study the effect of adsorbent size in filtration process.
- To study the effect of flow rates in filtration process.
- To examine and evaluate the removals of turbidity, suspended solids, BOD and COD.

1.4 Scope Of Research

Sample from Sungai kerian was taken to evaluate the value of turbidity, suspended solids, COD and BOD after the filtration process. The filtration process was conducted in Environmental Laboratory at School of Civil Engineering. This study was conducted to investigate the effects of flow rate and media size on removal efficiency of roughing filter.

1.5 Importance And Benefit

- A lot of benefit to the field of Civil Engineering especially in water treatment.
- Roughing filter is important to reduce turbidity an suspended solid concentration to a level adequate for slow sand filter operation.
- To determine the quality of water by removal of physical, biological and chemical characteristic.
- This project only discuss about horizontal roughing filter using limestone as media and it work base on adsorption principal

CHAPTER 2

LITERATURE REVIEW

2.1 Water Classification

Water can be classified by source. Portable water can be classified to groundwater or surface water. **Table 2.1** shows general differences between ground water and surface water (Davis , 1998)

2.1.1 Groundwater

Groundwater is generally uncontaminated but may contain aesthetically undesirable impurities. Groundwater is classified to its source ; deep or shallow wells. Municipal water quality factors of safety, temperature, appearance, taste and odor, and chemical balance are easily satisfied by a deep well source. High concentrations of calcium, iron, manganese, and magnesium typify well water. Some supplies contain hydrogen sulfide while others may have excessive concentration of chloride, sulfate, or carbonate.

Shallow wells are recharged by a nearby surface watercourse. They may have qualities similar to deep wells or they may take on the characteristics of the surface recharge water. A sand aquifer between a shallow well supply and the surface water course may act as an effective filter for removal of organic matter and as a heat exchanger for buffering temperature changes. To predict water quality from shallow wells, careful study of aquifer and nature of recharge water are necessary.

2.1.2 Surface Water

Surface water must be considered to be contaminated with bacteria, viruses, or inorganic substances which could present a health hazard. Surface water may also have aesthetically unpleasing characteristics for a portable water. Surface water supplies are classified as to either they come from a lake, reservoir or river. Generally a river has the lowest water quality and the reservoir is the highest. Water quality is largely influenced by pollution from municipalities, industries, and agricultural practices. Many rivers will show an increase in color and taste and in odor producing compounds. In warmth month, alga blooms frequently cause taste and odor problems.

Reservoir and lake sources have much less day to day variation than rivers. Additionally, the quiescent will reduce both the turbidity and color. As in rivers, summer alga blooms can create taste and odor problems.

Table 2.1 General differences between ground water and surface water (Davis , 1998)

Ground water	**Surface water**
Constant composition	Varying composition
High mineralization	Low mineralization
Little turbidity	High turbidity
Low or no color	Color
Bacteriologically safe	Microorganism present
No dissolve oxygen	Dissolved oxygen
High hardness	Low hardness
Hydrogen Sulfide, Ferum and Manganese.	Tastes and odors Possible chemical toxicity

2.2 Water Treatment

Treatment plants can be a simple disinfection, filter plants or softening plants. Commonly , a filtration plant is used to treat surface water and a softening plant to treat groundwater.

2.2.1 Filtration Plant

In a filtration plant, rapid mixing, flocculation, sedimentation, filtration, and disinfection are employed to remove color, turbidity, taste and odor and bacteria. Additional operations may include bar racks or coarse screens if floating debris and fish are a problem. During mixing, chemicals known as coagulants are added and rapidly dispersed through the water. The chemicals reacts with the desired impurities and form precipitates (flocs) that are slowly brought into contact with one another during flocculation. The objective of flocculation is to allow the flocs to collide and “grow” to a settleable size. Particles are removed by gravity (sedimentation). It is done to minimize the amount of solids that are applied to the filters.

Filtration is the final polishing of particles. During filtration the water is passed through sand or similar media to screen out the fine particles that will not settle . Disinfection is the addition of chemicals (usually chlorine) to kill or reduce the number of pathogenic organisms. Disinfection of the raw water is neither economical nor efficient. The color and turbidity consume the disinfectant thus requiring the use of excessive amounts of chemical. In addition, the presence of turbidity may shield the pathogens from the action of the disinfectant and thereby prevent efficient destruction. Storage may be provided at the plant or located within the community to meet peak demands and to allow the plant to operate on a uniform schedule. **Figure 2.1** illustrates the filtration plan layout. **Table 2.2** shows the pretreatment application.

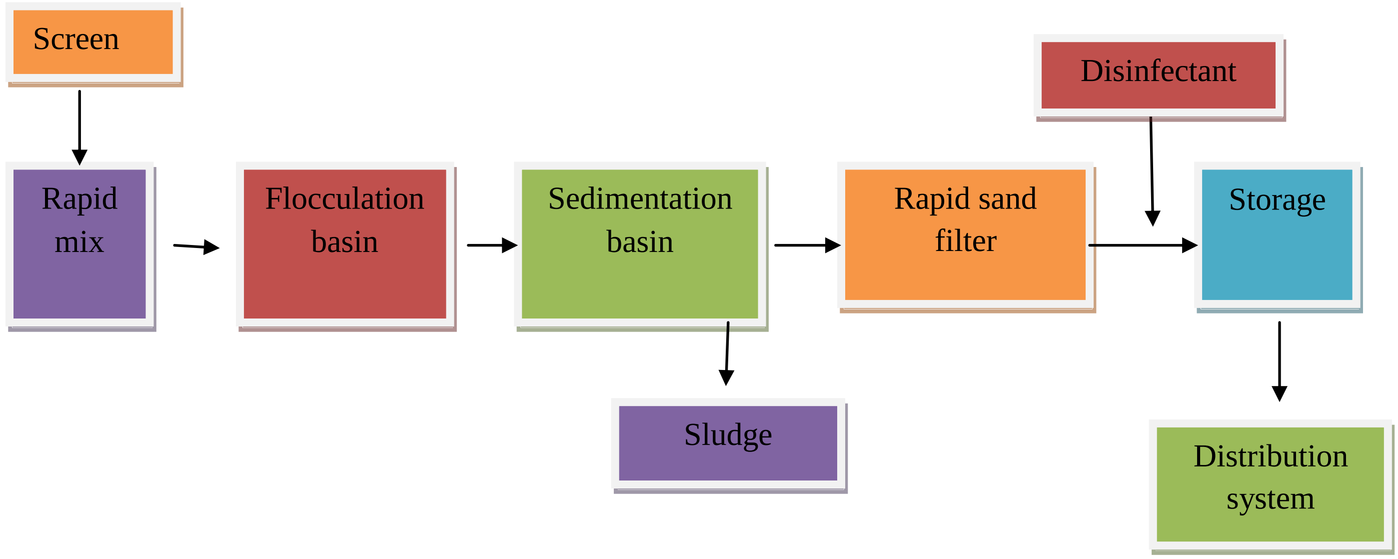


Figure 2.1 Filtration Plant Layout

Table 2.2 **Pre Treatment Application (Davis , 1998).**

Process	**Application**
Long-term Storage	It only removes sediments . There is a potential threat of growing algae. Efficiency rate for removal of suspended materials in it is from 50 to 70 percent
Waste Collection Application	Rubbish such as stones ,woods ,etc, which block or damage the equipment shall be removed and separated.
Preliminary Sedimentation	Only mineral particles; large than 20 microns, are removed; and its efficiency for removal of suspended particles is 30 to 50 percent.
Sedimentation and Flocculation	It needs a coagulant in regard to qualitative modifications of sensitive waters, efficiency of suspended particles removal is 90 to 98 percent.
Floatation	Needs a coagulant , and dissolved air stream and it is sensitive toward qualitative modification; efficiency for removal of suspended particles is 90 to 98 percent
Microstrines	Intruding minute particles; similar to algae , which can separate solids from water
Dynamic filter	For removal or decreasing the heavy load of suspended solids form water
Water filter or water basin filter	For removal or decreasing the load of suspended solids and maintenance of treatment plant.
Roughing filter	For removal of a high concentration of suspended solids, and loads of organic chemicals and microorganisms from water

2.2.2 Softening Plant

Softening plant utilize the same unit operations as filtration plants, but use different chemicals. The primary function of a softening plant is to remove hardness (calcium and magnesium). In softening plant, the design considerations of the various facilities are different than those in filtration plant. The chemical doses are much higher in softening, and the corresponding sludge production is greater.

During rapid mixing, chemicals are added to react with and precipitate the hardness. Precipitation occurs in the reaction basin. The other unit operations are the same as in a filtration plant except for the additional recarbonation step employed in softening to adjust the final pH. **Figure 2.2** illustrates the softening plant layout.

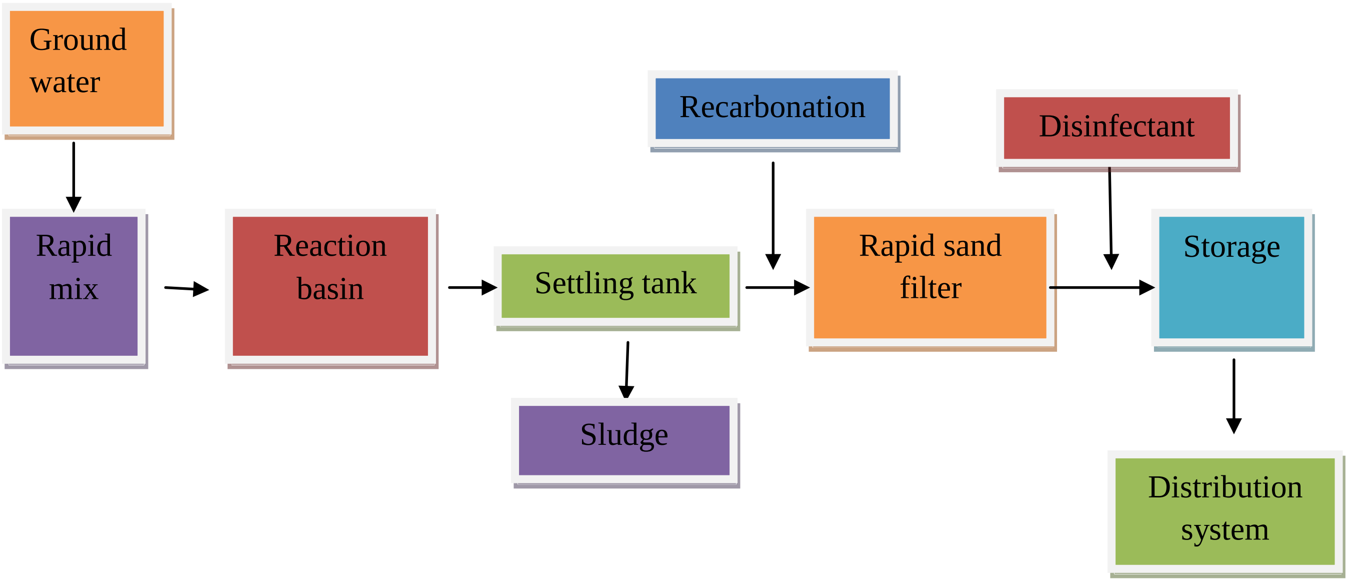


Plate 2.2 Softening Plant Layout

2.3 Roughing Filter

Filtration is the process of removing suspended solids from water by passing the water through a permeable fabric or porous bed of materials. Groundwater is naturally filtered as it flows through porous layers of soil. However, surface water and groundwater under the influence of surface water is subjected to contamination from many sources. Some contaminants pose a threat to human health, and filtration is one of the oldest and simplest methods of removing them. Federal and state laws require many water systems to filter their water. Filtration methods include slow and rapid sand filtration, diatomaceous earth filtration, direct filtration, packaged filtration, membrane filtration, and cartridge filtration. (A national drinking water clearinghouse fact sheet, 1996)

Roughing filters are physical filters and intended to retain the majority of the suspended solid (SS). They are applied to treat surface water of high turbidity over prolonged periods. The grains are of successively decreasing sizes arranged in layers or compartments and usually range from 25 mm down to 4 mm. The larger grains allow deep deposit penetration. The bulk of the SS is retained in the first coarser grains compartment which has a high deposit retention capacity at the expense of only low headloss. The subsequent finer grains have more of a polishing function. (Ahsan, 1995)

2.3.1 Roughing Filtration Particle Removal Mechanism

There are three mechanisms of suspended particles removal in solution. The mechanisms are surface (or cake) filtration, straining filtration, and physico-chemical filtration. **Figure 2.3** illustrates primary particle removal mechanisms in granular filtration.

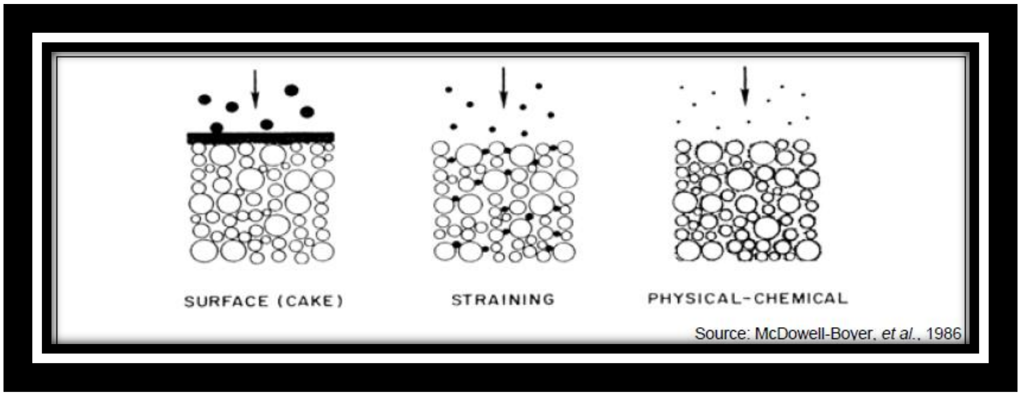
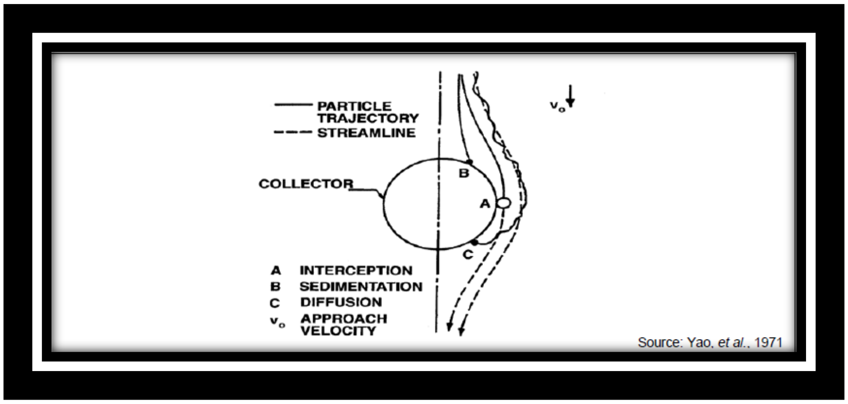


Figure 2.3 Primary particle removal mechanisms in granular filtration (McDowell, et al., 1986)

2.3.2 Physico-Chemical Filtration

Physico-chemical filtration occurs when particles are much smaller than the size of filter (the common case in roughing filtration), Particle removal is dependent on the successful transport and attachment process of a suspended particle to a media. There are three principal mechanisms leading transport of particles to a single collector as shown in **Figure 2.4** .



Source: Yao, *et al.*, 1971

Figure 2.4 Mechanism of particle transport to a single collector surface (Yao, et al, 1971)

2.3.3 Attachment Process

Physico-chemical conditions unfavourable to particle-collector attraction are common under natural condition. In such cases, the theoretical SCE (Single collector efficiency) ηo, will be more than actual SCE, η. An empirical collision efficiency (or attachment) factor, α, accounts for the probability such that $\eta = \alpha\eta o$. An empirical collision efficiency factor is determined experimentally from :

1) Removal efficiencies of suspended particles through porous media and theoretical values of single collector efficiency, or

2) Flocculation rates of particles undergoing mixing in a batch reactor (Collins, 1994). Attachment occurs where there is no contaction between particle and collector. When $\alpha = 0$, the water is completely stabilized. Attachment occurs when $\alpha = 1$. When

the water is completely destabilized, there were contaction occurs between particle and collector grain surface.

2.3.4 Surface And Straining Filtration

Surface (or cake) filtration results from the closing off of porous media pore openings, caused by particles screening at the porous media surface . Cake filtration occurs when the ratio of the collector diameter (dc) to particle diameter (dp) is less than 10 (McDowell-Boyer, *et al.*, 1986). Straining filtration occurs when particles penetrate into porous media but are later lodged in the filter due to their large size. Straining filtration is likely to occur for the range of $10 \leq dc/dp \leq 20$ (McDowell-Boyer, *et al.*, 1986). In addition, Edwin et al. (2006) found that surface and straining filtration are not likely to play an important role in roughing filtration because :

- Large particles (>20 μm) are heavy and will be removed prior to roughing filtration by methods, such as sedimentation (Wegelin, 1987) assuming particle densities allow large particles to settle faster.
- Larger particles are removed earlier using proper roughing filter design. The presence of larger media allowing progressively smaller particles to penetrate deeper into the filter, where they come into contact with smaller sized media.
- In horizontal roughing filters, filter cake development is limited by particle drift. In vertical upflow roughing filters, filter cake development is limited by secondary particle

detachment. For all configurations, filter cake development is limited by periodic filter maintenance.

2.4 Types Of Roughing Filter

2.4.1 Horizontal Roughing Filter

A horizontal-flow roughing filter (HFRF) consists of a box of 3-4 compartments filled with grains of progressively smaller size in each compartment (**Figure 2.5**). The raw water flows through the inlet channel with weir into an inlet chamber. The water is evenly distributed over the vertical filter cross section. The filter media are decreasing in size in the direction of flow. The water is collected in outlet chamber. Finally the treated water is discharged through the outlet channel. In addition, Ahsan (1995) found that the length of the filter box is usually 5-9 m, and its height is limited to 1.5 m to allow comfortable manual cleaning when required. Similar to that, the width varies from 2 to 5 m according to required capacity (Ahsan, 1995).

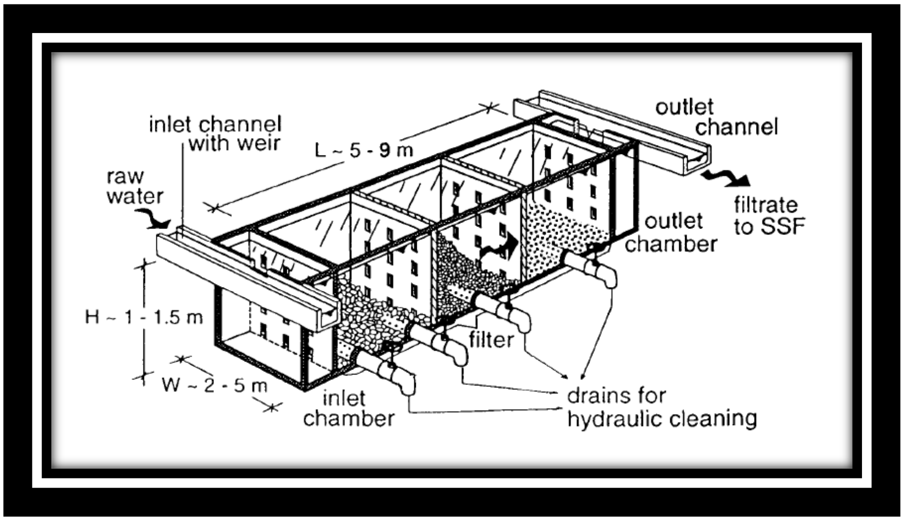


Figure 2.5 Layout of a 3 compartment horizontal flow roughing filter (Wegelin and Schertenleib, 1993).

2.4.2 Vertical Roughing Filter

Vertical-flow roughing filters run either as down flow or up flow filters. The raw water is either supplied at the filter top or at the filter bottom. Compare to HFRF (Horizontal Flow Roughing Filter), the vertical flow roughing filter provide a simple self cleaning mechanism. In fact, the floor space requirement is smaller than HFRF.

The filter media of vertical-flow roughing filters are completely submerged compared to HFRF. Onyeta (2009) reported that the filter media like gravels, coconut fiber and broken burnt bricks covered by a water volume of about 10 cm depth. A layer of course media at the top of the filter provides the water shading, thus prevent an algae growth, in case that pretreated water is exposed to the sun

Drainage facilities for vertical roughing filter consist of perforated pipes or a false filter bottom system, on the floor of the filter boxes. The water flows through the subsequent 3 filter units via a special inlet and outlet compartments. It can be seen in **Figure 2.6** (Nkwonta, 2009) .

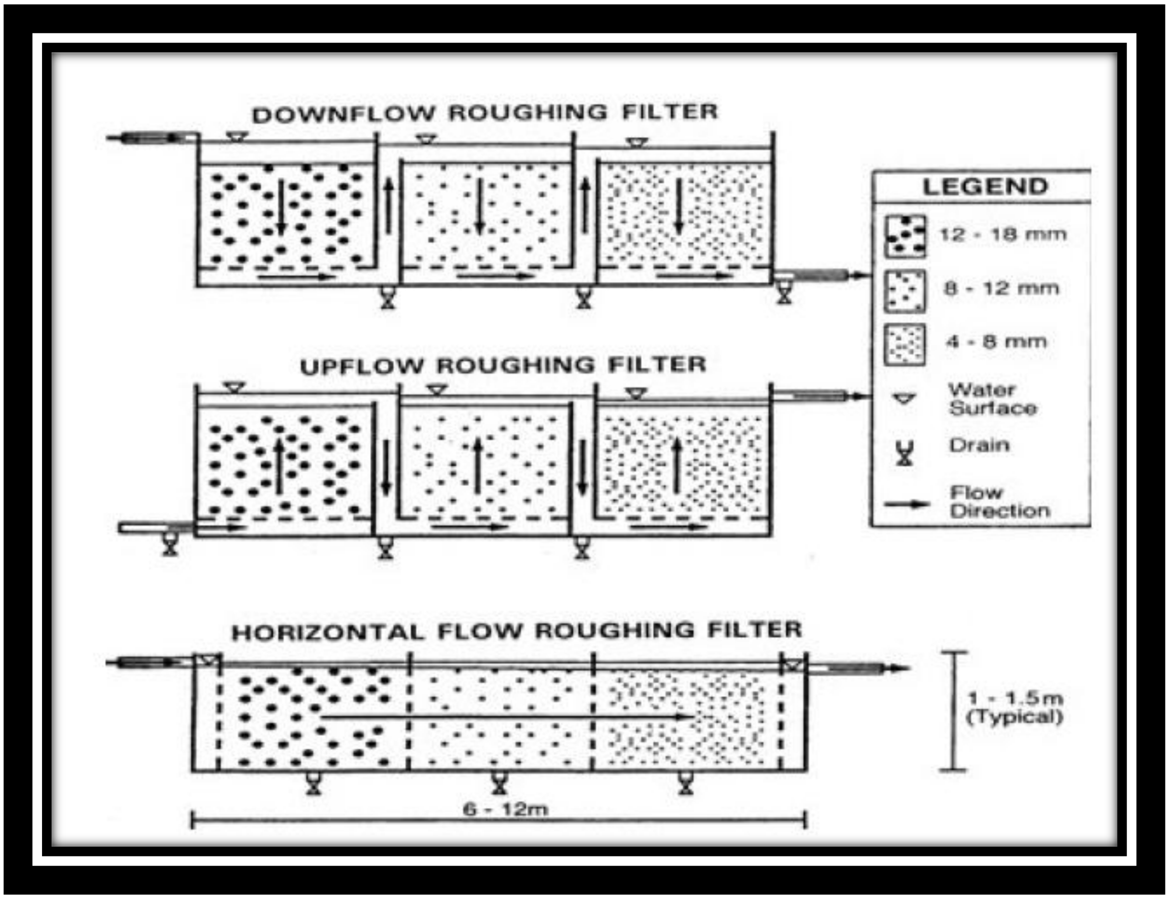


Figure 2.6 Diagram of horizontal, up flow and down flow roughing filters (Wegelin, 1996)

2.5 Horizontal Roughing Filter Design

HFRF (Horizontal Flow Roughing Filter) can be divided into several compartments. Wegelin (1996) reported that HFRF consists of an inflow control, an inflow distribution device, the filter, an effluent collection device, an outlet control and a drainage system. A general HFRF layout is shown in **Figure 2.6**. Similar to that , Wegelin et al. (1987) stated that the filter itself can be divided into three or four compartments with grade gravel filter media. In order to maintain a constant volume of water in the filter, Wegelin et al. (1897) and Sittivate (2001) revealed that the outlet control should be placed at the top of the filter. **Table 2.3** gives general filter dimensions from Wegelin et al., (1987) and Collins et al., (1994).

Table 2.3 General HFRF Dimensions (Wegelin et al., 1987 and Collins et al., 1994)

Dimension	**General value (m)**
Length	6 – 12
Width	2 – 4
height	1 - 2

2.6 Turbidity Range and Media Sizes

Quartz sands and gravels are the common media types used in a roughing filter. in addition, Graham (1988) reported that the filter media can be any materials that are clean, insoluble, and mechanically resistant material. In a research work carried by Wegelin (1987), the removal efficiency in roughing filter is affected by the size and shape of macro pores in the filter. The effect of surface porosity and media roughness are insignificant on removal efficiency . Filter media using calcite limestone, basaltic river rock, and limestone-amended basalt in HFRF has been studied by Rooklidge and Ketchum (2002). Achieved results from this study found only marginally improved efficiency (7%) for calcite amended basalt filters over unaltered filters. High removal efficiency was achieved using smaller filter media size (Collins, 1994 : Wegelin, 1987).

The use of multiple grades of filter media in a roughing filter promotes the penetration of particles throughout the filter bed. Large filter media size provides large storage capacities and small filter media size provides high removal efficiency. The filter media are decreasing in size in the direction of flow. In order to increase filter pore space (storage capacity) as well as to promote filter cleaning, the uniformity of filter media fraction is maximized (Boller, 1993). Common grades of media used in roughing filters are provided by Wegelin (1996) and shown in **Table 2.4.** **Table 2.5** summarizes the effective gravel medium sizes by different research.

Table 2.4 Common Grades Of Media Used In Roughing Filters

Roughing filter decription	**Filter media size [mm]**		
	1st fraction	**2nd fraction**	**3rd fraction**
Coarse	24-16	18-12	12-8
Normal	18-12	12-8	4-8
Fine	12-8	8-4	4-2

Table 2.5 Horizontal Flow Roughing Filter Medium Size Ranges

Range of gravel size [cm]	**Source**
0.3-4	Logsdon et al., 2002
0.3-3.5	Jayalath et al., 1995
0.4-2	Wegelin et al., 1987
0.5-5	Boller, 1993
1-2	Sittivate, 2001

The SANDEC RF Manual (Surface Water Treatment by Roughing Filters - A Design, Construction and Operation Manual) design guidelines suggest that for average turbidities above 200 NTU upflow roughing filters in series (UGFS) or a HRF be used (Wegelin, 1996, XII-4). **Table 2.6** shows the comparison of media filtration options.

Table 2.6 Comparison of Media Filtration Options (Galvis et al, 2006; Wegelin, 1996)

	Filtration Rate (m/h)	**Media Size (mm)**	**Length or Height (m)**	**Raw Water Turbidities (NTU)**
UGFL (one compartment)	0.3-1.0	25-19 19-13 13-6	0.20-0.30 0.20-0.30 0.20-0.30	50-150 NTU
UGFS (three compartments)	0.3.1.0	25-19 19-13 13-6	0.60-1.0 0.60-1.0 0.60-1.0	50-150 NTU
HRF (three compartments)	0.3-1.5	12-18 8-12 4-8	2-4 1-3 1-2	50-150 NTU short peaks 500-1000 NTU

Although the high removal efficiency can be achieved by using small media, coarse media is important in order to provide a storage space of settleable solids and ease the burden of frequent filter cleanings as shown in **Figure 2.7.**

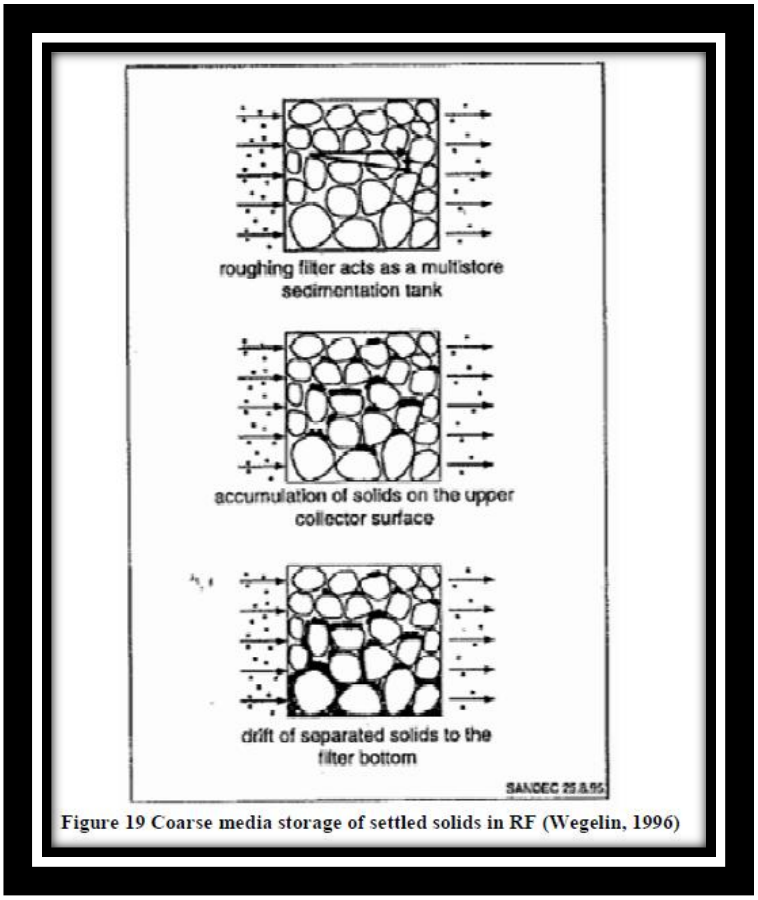


Figure 19 Coarse media storage of settled solids in RF (Wegelin, 1996)

Figure 2.7 Coarse media storage of settled solids in roughing filter (Wegelin, 1996)