FILTER MEDIA

This Project is submitted to the
Department of Civil Engineering,
Ahmadu Bello University, Samaru, Zaria

In partial fulfillment for the award of

ASSOCIATESHIP IN CIVIL ENGINEERING

by

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September, 1974

ACKNOWLEDGEMENT

The Author wishes to take this opportunity to express his sincere thanks to Professor B. Z. Diamant who supervised him throughout the project period for his expertised advice and useful guidance.

I should also like to express my sincere thanks to all those who have helped in any way to make this project a success.

C O N T E N T S

INTRODUCTION

The purpose of the project is to explain precisely what a filter media is, its characteristics and reaction when water is brought in contact with it.

Therefore for anybody to be able to explain all what is mentioned above a thorough knowledge of the general aspects of filtration is essential.

Filtration in its broadest term is a process by which all the suspended and colloidal impurities present in waters are separated by passing the waters through a porous or open-textured media such as sand or crushed anthracite (coal). The impurities separated are left behind in the pore openings or upon the bed of the medium itself. This process is also an important and also active process in the purification of the natural ground waters. It was first introduced into a large scale use for the clarification of water pumped from the river Thames, in the year 1829 by a British engineer called James Sampson for the Chelsea Water Board.

Since most of the water cooperations obtain their water from the surface source. The quality of this water has always been deteriorated as a result of contermination by chemicals and other organic contents e.g. algae.

It is as a result of this situation Water Supply Management is faced with problems of finding the most suitable and efficient filter media.

In practice filtration can not be complete unless it embraces the following operations:

1. Screening
2. Sedimentation
3. Flocculation
4. Biological Activities

1. Screening

This takes place at the surface of the filter bed, where the water enters the pores of the filter bed. The substances which are larger than the pore openings are removed. When resistance to filtration has amounted to an excessive value, the removal of the mat then becomes necessary. This is normally done by scraping the first 2 - 3 inches (50 - 75mm) of the bed and then washed to remove all the impurities before taken back.

2. Sedimentation

This is the settling down of the suspended particles in water. Hazen has proposed that the removal of suspended particles by filter is similar to the sedimentation in a basin fitted with large number of trays. The particles sizes should naturally be smaller than the pore openings of bed of filter so that the sedimentation can take place. It is found that a cubic meter of spherical sand grain of 5×10^{-2}cm diameter contains all together about 40% void space 0.6×10^6. Particles with a gross surface area of $9.15 \times 10^9 \times 11.25 \times 10^{-4}$ = 7.2×10^3 M^3.

Since slow sand filters are about 1 meter deep and ordinarily receive about 10% of the amount of water per unit sufrace area that settling basins do, it also follows that slow sand filters in comparison with settling tank can be expected to remove also particles with $\frac{1}{4000}$ settling velocity and of less than $\frac{1}{60}$ the diameter. The efficiency of filter is observed to be decreasing with temperature.

3. Flocculation

The flocs which build up make it difficult for the impurities to pass through the pore openings of the filter bed. Thus retained over the bed to be subsequently scraped off.

TYPES OF FILTERS

Filters are generally designated with respect to their constituents materials. In practice there are various types of filters normally identified by their media, some of which include -

1. Granular Water and Waste Water filters.
2. Diatomaceous earth filters.
3. The Domestic or ceramic filters.

(a) Granular Water and Waste Water filters

There are two common types of granular filters. These differ both structurally and hydraulically. They are namely the

(a) slow sand filters (S.S.F.)

(b) rapid sand filters (R.S.F.)

Sand and gravels are the main constituent materials of these filters. Apart from their operations the two filters are more or less identical in arrangement.

In the slow sand filters the filters are intended to operate at a relatively slow rate (1 - 10 mgd), while the rapid filter is intended to operate at a relatively high rate.

Also the removal of suspended matter and its penetrations are confined to the surface layer in the case of slow sand filters, while in the rapid sand filters the sand is cleaned.by back washing with part of the filtered water. Back washing is the opposite of the normal filtration operation.

In the slow sand filters there are more sand than in the rapid filters. The sand in the slow sand filter is about 105cm (42") supported by about 30cm (12") of gravel. The rapid sand filter consists of 95cm sand supported by about 45cm (18") of gravels.

The tricling filters which are used in the secondary treatment of settled wastes is another form of granular filters. It is made of stones ranging between 1½ - 3 inches. Its function is to separate slime from the treated sewage.

(b) Diatomaceous earth filters

These are also another types of water filters. They are used as mobile units for the purification of water in the field and also used as stationary units for swimming pools.

The filtering medium is a layer of diatomaceous earth built on a porous septum, when a slurry of diatomaceous earth is recirculated through the septum until a firm layer is formed on the septum. The resulting precoat is supported by the septum, which serves also as drainage system. The water is strained through the precoat unless the applied water contains so much turbidity that the unit will maintain itself only if additional diatomaceous earth, called body feed, is introduced in to the incoming water and preserves the open texture of the layer.

Skeletons of diatom 0.5 to 12μ in sizes compose the diatomaceous earth . Precoating requires 0.1 to 0.5 lb. of diatomaceous earth per sq. ft. of septum. Body feed is added in a ratio of 1.25:1 on dry basis when waters contain in organic silts. For organic slimes the ratio is stepped up to about 3:1. The filter operates at rates of 2.5 to 6 gps per sq. ft. Back washing rates of 7 to 10 gpm per sq. ft. remove spent filter cake.

(c) The Domestic or Ceramic filters

There are several types of ceramic filters, such as pressure filters, non pressure filters and filter pumps, and there is a wide range of ceramic media having different pore sizes. The heart of any of these is the filter candle, and the method of getting water through the candle is only a matter of convenience. Only clean water should be used with ceramic filters otherwise with cloudly or turbid water, the candles clog very quickly.

Coarse-grained filter candles are useful in removing suspended matter, helminth ova, cercariae and cysts. They may be only partially effective in removing the smaller disease organisms, and consequently water should be chlorinated or otherwise disinfected after passage through a coarse-grained or industrial-type filter.

Porcelain filters are made with pore sizes from a maximum pore radius of 50μ or larger down to 0.30μ. Examples of such filters are chamber land L_2 and the selas 015. To be satisfactory for water purification, the pore radius should be about 1.5μ. These and similar fine-grained porcelain filters will remove all disease organisms usually found in drinking water, and it is quite safe to use water after passage through such a filter without further treatment. Porcelain filters must be cleaned and boiled at least once a week even if they are not clogged but generally the cleaning is effected when the filters become clogged.

Filler candles can be mounted in a gravity type filter, which consists of two reservoirs with candle or candles attached to the upper reservoir as shown in the fig. 1. Water is simply poured in at the top, trickles through the ceramic candles and is stored for use in the lower compartment.

FILTERING MATERIALS

The natural silica sand is the most common filtering media, but there are other finegranular filtering materials such as crushed anthracite (coal).

(a) Sand

It is usual to specify the size and grade of sand to be used, example the common grade of sand used is said to pass a 16 mesh and be retained on 30 mesh sieve or in grain size that is all sand between .2mm to 0.4m, or in the British standard sieves can be said to pass through No. 25 and be retained on No. 72 sieves.

The size of sand most suitable for a particular purpose will vary considerably. The finer the suspended particles to be removed the smaller the size of the sand to be used in order to increase the surface area for the same depth of bed.

This explains why it is possible to treat successfully a large number of different waters using same size of sand.

Where filter medium is not too coarse for a particular water, can be too coarse for another water, this is shown by the fact that the turbidity of effluent begins to increase at a low rate of head loss through the filter bed.

The advantage of working with a standard filter sand size and allowing ample depth to the bed is to provide for possible variations in quality of the raw water. The arrangements for the cleaning of the filter depends largely on the size of the filter media.

Selection of Sand

Experiments show that very fine sand is considerably more efficient in removing bacteria than ordinary or coarse sand, but within ordinary limits of size (0.2 to 0.4 mm) there is but little difference in efficiency. The fine sand however; cause steadier action and prevents disturbances due to scraping, they also cause a greater loss of head in the filter and so make the action more uniform over the filter area. On the other hand the sand becomes clogged sooner than the coarse and involves therefore more expensive operation because of the constant cleaning. For waters containing very fine sediments, fine sand are likely to become clogged to considerable depth, requiring the removal of too thick a surface layer or even the whole sand bed.

In practice the size of sand to be used varies from 0.2 to 0.4mm, or average about 0.3mm. The sand should be fairly uniform in size of grain (uniformity coeficient of 2 - 25). If the particles vary greatly in size. It will be difficult to wash and in fact will have much fine particles removed in the process, thus increasing the effective size. It is very important that the sand should be the same grade in all parts of the filter in order that the frictional resistance, and therefore the rate of filtration shall be uniform.

Frequent analysis should be made as the sand is delivered to the works. Regarding other requirements; the sand should be free from clay, and if necessary be washed. The chemical composition is also important, as a sand containing a considerable amount of lime will increase the hardness of the water. It has also been found that the presence of aluminous and calcareous material increases the resistance to the flow of water.

(b) Anthracite

Crushed anthracite (coal) has been successfully used as filter medium in place of sand. The chief difference between the two materials is their specific gravity which allows the anthracite to be suspended in upward stream of the water moving at lower velocity than is required for a sand of equivalent size. This characteristic permits a coarser grading of media to be used in a filter initially designed for sand and may result in improved operation if the sand grading was too fine for the duty required, there is, however, no real advantage in the use of anthracite in place of correctly graded sand.

Anthracite is, however, a crushed material and as such not as rounded as good filter sand should be. It is therefore liable to have its corners rubbed off in the course of time and initially at any rate a fair proportion of fine particles develop on top of the filter beds and have to be removed by scraping for the proper operation of the filter.

Silica sand is not inert to hot caustic solutions and anthracite is therefore normally incorporated in a filter after hot process precipitation softeners are used.

GRAIN SIZE AND SHAPE

Granular filtering material differ in size and size distribution, in shape and also shape variations, density and chemical combination.

Size is three dimensioned and generally implies to volume. Shape in particular, is a matter of surface area in relation to volume. Only on the ideal case of regular solids can single measurement identify both the volume and surface area of a solid. The so called - diameter of irregular particle whatever its means of determination can be is just but approximate volume and surface area.

The particles of any given sample of sand vary much in size, but as regards the size of the interstices, and the percolation of water, it is obvious that the size of the finer particles rather than the size of coarser determines its effective size. The term effective size as used in the sand analysis was defined as also the measure of uniformity known also as the uniformity co-efficient.

The method employed in analysing a stock of sand is by passing a representative portion of the stock through a series of calibrated standard sieves. After the sample is sifted through the sieves. The portion retained on the pan is weighed first, then the successive sample portions held between adjacent sieves weighed and recorded. The cumulative of these weights are then recorded. The weights on each sieve are then converted into percentages by weight equal to or less than the size of separation of the over laying sieve. The cumulative frequency distribution curve can be plotted. For many natural granular material this curve approaches geometric normality. Therefore assumes an almost straight line in which interpolation is facilitated. The geometric mean Mg and also the geometric standard diviation 6_g are then useful parameters of the central tendency and variation.

Care must be taken to have the sand thoroughly dry before sifting.

Graph No. 1

Analysis of a Stock of Sand

Size of Separation
cm x 10^2

1.05

1.49

2.10

2.97

4

Analysis of Stock Sand

Example taken from Text book

Size of Separation	Cumulative Weight
cm x 10^2	%
1.05	0.2
1.49	0.9
2.10	4.0
2.97	9.9
4.2	21.8
5.9	39.4
8.4	59.8
11.9	74.4
16.8	93.3
23.8	96.8
33.6	100.0

PREPARATION OF FILTER MEDIA SAND

Natural run-of-bank sand may be too coarse, too fine or too non uniform for a projected filter. Specified sizing and uniformity can be obtained within economical limits by screening out the coarse grains and washing out the fines.

If the filter sand is specified in terms of effective size and non uniformity coefficient and a sieve analysis of the stock has been made. The coarse and fine proportions of stock sand are known. These portions which are going to be removed from the stock are the functions of P_{10} and P_{60} namely the percentages of the stock sand smaller than the desired effective size and the 60 percentile respectively. This can be properly explained as follows:

1. Because the sand lying between the P_{60} and P_{10} sizes constitutes half the specified sand, then percentages of usable stock is -

   $P_{usable} = 2\ (P_{60} - P_{10})$

2. Because the specified sand can contain but $\frac{1}{10}$ of the usable sand below the P_{10} size, the percentage above which the stock sand is too fine for use is -

$$P_{\text{too fine}} = P_{10} - 0.2\,(P_{60} - P_{10})$$

Provided that the grain size associated with the sand that is too fine is equal to or greater than the smallest size of the sand to be included in the filter.

3. Because a percentage of stock sand equal to $P_{\text{usable}} + P_{\text{too fine}}$ has been accounted for, the percentage above which the stock sand is too coarse is -

$$P_{\text{too coarse}} = P_{\text{usable}} + P_{\text{too fine}} = P_{10} + 1.8\,(P_{60} - P_{10})$$

Before sand is placed in the filter, all fines can be washed out of it in sand or grit washer. Washers of the same kind can also cleanse sand removed from a clogged filter, and remove grit and other organic matter.

FILTER DESIGN

In selecting a sand for filtering purposes, the important properties are its size and uniformity of grains. The presence or the absence of fine material and organic matter, and also its chemical composition.

The dimensioning of filters and their apputenances depends on the entrant water quality, filter type, process and hydraulic loading, method and intensity of cleaning, nature and size of filtering material, depth of filter bed and the prescribed quality of the product water. Unless a pilot filter provides informations on the following observations.

1. The observed responses of a specific water to treatment in a plant being designed for this purpose.

2. The associated responses of the filter or filters examined, it is common to start with design values that have stood the tests of experience and to modify these values in the light of new informations and wanted objectives.

Some filters are expected to be no more than polishing units that separate residual floc from well-coagulated well settled water. Such filters can be relatively shallow, coarse-grained, high rate units producing a clear effluent that is emenable to disinfection. Rough filters so called because they only prepare water for further filtration may also be designed in this nature. Placed in advance of slow sand filters they have been operated with or without coagulation. By contrast filters are normally designed as relatively deep, fine grained, low rate units if they are intended to -

1. Offer an effective barrier to water borne pathogens.
2. Treat water containing much floc or
3. Serve as reacting units for floc formation and removal after dosage of the applied water with coagulant.

Even for waters of fairly contrast and constant composition, it is not yet possible to prescrible unique or optimizing combinations for filter depth, layered arrangements of filtering media (size, shape and density) and rates of filtration. It is doubtful, too, whether designers would wish to dimension their units narrowly. Raw water quality is bound to change in time as well as season, preparatory processes are certain to improve it necessary, and demands on productivity are sure to be raised concurrently. Thus, built in flexibility becomes an essential design requirement.

Performance objectives to be reconciled are terminal head loss, standard of the effluent quality (for instance turbidity) and the length of filter runs. As grain size is increased, head loss drops markedly at upper levels, but effluent turbidity increases relatively rapidly. As rates of filtration are upped, head loss and turbidity rise relatively fast, at all filter levels. In coarse grained units, filter runs ended at a given head loss are relatively longer than in a fine grained units, but filter runs ended at a given turbidity are relatively shorter.

Bed depth

In designing a filter it should be noted that sand forms the filtering medium, the gravels serves simply to collect the filtered water with little or no resistance to flow. The thickness of sand for a normal filter bed is usually between 2 to 3 ft. (60 - 90 cm). The gravels layer is about the same and the water depth is 3 - 4 ft. (90 - 120 cm). In some filters the layer of fine sand is under lain by a thick lay of coarse sand.

The design depth of rapid sand filters is generally related to grain size, terminal head loss and terminal turbidity. In an analysis of bed performance, Hudson concluded that in adequately filtered water breaks through rapid filters when

$$B = Q\, d^3 \frac{h}{l}$$

Here Q is the rate of filtration in gallons per minute per square foot of the filter (litres per minute per square metre) d is the sand size in centimetres, h is the terminal loss of head in metres, l is the depth of bed in cm and B is the break through index that assumes the following magnitudes of different influent water at 50°F.

Influent Waters at 50°F

	Response to coagulation	Degree of Pretreatment	Value of B
1.	Poor	Average	$4x10^{-4}$
2.	Average	Average	$1x10^{-3}$
3.	Average	High	$2x10^{-3}$
4.	Average	Excellent	$6x10^{-3}$

For temperatures other than 50°F, vislosity effects can be allowed for by multiplying the break through index by 60 (T + 10).

Multi layered filters, often referred to as mixed-media filters, stimulate counter current operation by being composed of successive layers of coarse but light filter grains on top of increasingly finer but heavier particles. Such filters must preserve layered structure during back washing and resettling. For this purpose, the light grains of largest size in an upper layer must rise higher and settle more slowly than the heavy grains of smallest size in the layer next below.

Equal expansion during back washing is identified by certain equations and settling is hindered in accordance with these equations.

$$du/_{dl} = (\psi_l / \psi_u)\ ((P_l - P)\ \ (P_u - P))^{\frac{1}{2}}$$

or $$\frac{du}{dl} = \frac{\psi_l}{\psi_u} \left(\frac{P_l - P}{P_u - P}\right)^{\frac{1}{2}}$$

Where the subscripts u and l respectively denote the largest grains within the upper layer and the smallest within, the lower layer. It follows that mixing during settling as well as during expansion determines the maximum allowable ratio of the grain sizes in the layers. Because the conditions of flow and specific shape of filter grains are normally uncertain a value of $\frac{du}{dl}$ smaller than that from the equation would be employed.

HYDRAULICS OF FILTRATION

Hydraulics of filtration cannot be said to be unconnected with the nature of the filtering material, that is, its size, shape and chemical combination.

At velocities commonly employed in granular water filters, flow is normally laminar and obeys Darcy's law V = KS, where V is the face or approach velocity of the water above the sand bed, $S = h/l$, h is the head loss, L is the depth of the bed of sand and K is Darcy's coefficient of permeability. Identifiable components of Darcy's k are the density ρ and viscosity μ of the water, the porosity f of the bed and the size and the shape of the component sand grains that established the surface area A of the grains with in the bed relative to their volume V.

Specifically, the resistance of a clean bed of sand to the filtration of clean water is given by the Blake Kozeny equation.

$$h/l = \left(\frac{k}{g}\right)\left(\frac{\mu}{\rho}\right)V\,\frac{(1-f)^2}{f^3}\,(A/V)^2$$

Here, after all recognizable factors have been introduced into Darcy's coefficient of permeability, K becomes a residual dimension less coefficient that assumes a magnitude close to 5.0 under most conditions of water filtration. The porosity factor, $(1-f)^2/f^3$, derives in part from the conversion of the approach velocity term, V into an interstitial velocity term $V/_f$, and in part from identification of the hydraulic radius, r of the interstitial channel as

$$r = \frac{\text{Cross sectional Area of flow x length of flow}}{\text{Wetted perimeter of channel x length of flow}}$$

$$r = \frac{\text{Volume of water in the interstices}}{\text{Surface area of sand.}}$$

Because the volume of water in the interstices is f (pore volume of the bed) and the bed volume is $V/(1-f)$.

$$r = \frac{fv}{1-fA} = \frac{f4d}{1-f6}$$

In terms of the size and shape of its constituent sand grains, therefore the rate of head loss becomes

$$h/_1 = (\frac{k}{g})\nu \, V \, (\frac{1-f}{f^3})^2 \quad (6/_{4d})^2$$

or

$$h/_1 = (k/_g)\nu V \, (\frac{1-f}{f^4})^2 \quad (s/_d)^2$$

Here the kinematic viscosity μ has replaced the ratio μ/ρ. These equations can be derived by (1) Weisback - Darcy equation (2) Considerations entering into the settling of particles and dimensional analysis.

In terms of grain size, shape and diameter which establishes the sphericity ψ = ratio of surface area of the equivalent volume of a sphere to the actual or true surface area of the sand grain.

$$\frac{h}{l} = \frac{k}{g} \frac{\mu}{\rho} V \frac{(1-f)^2}{f^3} \left(\frac{A}{V}\right)^2$$ can be as above.

The table indicate the values of ψ, s and f for sand used in rapid sand filters.

Description	ψ	s	f
Spherical	1.00	6.0	0.38
Rounded	0.98	6.1	0.38
Worn	0.94	6.4	0.39
Sharp	0.81	7.4	0.40
Angular	0.78	7.7	0.43
Crushed	0.70	8.5	0.48

Hydraulics of Stratified beds

In a clean filter, stratified by back washing the head loss is the sum of the losses in successive sand layers. Because the thickness of each of n layers is closely proportioned to the fractional weight, p of sieve size d becomes

$$h/_1 = (\frac{k}{g}) \nu V \frac{(1-f)^2}{f^3} (6/_4)^2 \sum_{i=1}^{n} (P_i/d_i^2)$$

Here the diameter d_i is an average diameter such as geometric mean diameter or square root of the product of the upper and lower sieve sizes representing the fraction P_i of the analysed sand, normally the values of reasonable sizes and fractions are respectively those of the adjacent sieves employed and the proportion P_i of the sand trapped between them. However, it is possible to read usable values also from the plotted analysis.

Hydraulics of Unstratified beds

In an unstratified bed of homogeneously packed sand, each component faction, P_i of size d_i contributes its share to the total area, the individual area volume ratio being $6/(4/d_i)$ for uniform sphericity, therefore is:

$$A/V = 6/\psi \sum_{i=1}^{n} P_i/d_i$$ and

$$h/l = (\frac{k}{g}) \; V(\frac{1-f}{f})^2 \; (6/\psi) \; \sum_{i=1}^{n} P_i/d_i)^2$$

WASHING OF FILTERS

The removal of solids impurities is brought about in various ways, which of them exerts the controlling influence depends entirely on the circumstances. At beginning of a filter run, fine-grained, non-stratified filters act primarily as strainers, slow sand filters are examples. They usually accumulate most of the impurities at the sand surface in the top 50mm (2 in.) of the sand bed. Larger microbic populations derived in the first instance from the applied water multiply as they flourish on the accumulated organic matter.

Most granular water filters remove particulates smaller than the passages between adjacent grains with help of electro magnetic induction. This can be explained by the concept of a filter as possessing in the aggregate a relatively large surface area in contact with water passing through with its impurities. Then come the surface forces to play their parts.

The substances removed during filtration are distributed unevenly. Interstices are narrowed however, by the accumulation of the impurities deposit. But the particles entering the pores spaces of the bed sink deep into it.

In fluidized beds the grain surfaces are scoured clear of the deposits by the repeated operation of abrasive contact between the moving grains.

The hydraulics of Back Washing

The impurities transferred from the applied water to the filter together with their coagulating and precipitating agents clog its pores and increase the hydraulic loss of head. The time rate at which head loss rise depends on sand size, porosily, filtration rate and amount and character of the suspended matter in the applied water.

The terminal head loss is usually established at a value at which the bed and its under drainage system come under partial vacuum or negative head within the bed, the head becomes negative when the loss of head through the overlying bed depth exceeds the static head. Variations in suspended matter removal and filter grain size may cause negative heads to appear first at intermediate depths. Toward the end of their runs, when any part of the bed goes under a partial vacuum, dissolved air begins to be released. The filter then becomes air bound, head losses rise sharply, and filter out put capacity drops rapidly. This situation makes it essential for back washing to take place.

During back washing the sand bed expands and is kept in suspension. For sand to be in suspension the frictional drag must be equal to the gravity. The following equations can be employed in explaining the concept of the hydraulics of back washing.

$$h \rho g = L_e (\rho_s - \rho) \quad (1 - f_e)$$

Where f_e = the porosity ratio of the expanded layer of thickness le

$$\frac{h}{le} = \frac{(\rho_s - \rho)}{\rho} \quad (1 - f_e), \quad \rho_s = \text{density of sand}$$

$$= \frac{\rho_s - \rho}{\rho} \quad (1 - f_e) = \frac{ke}{g} \nu V \frac{(1 - fe)^2}{fe^3} \left(\frac{6}{\psi} \frac{1}{d}\right)^2$$

Where $k_e = \phi (fe) = 4.0$

If the i^{th} layer consists of size d_i the equation is reduced to

$$\frac{fei}{1-fei} = \frac{k}{g} \frac{\nu}{\rho_s - \rho} V \left(\frac{6}{\psi d}\right)^2$$

For such layer the ratio of expanded depth leitothe in expanded depth li is

$$\frac{lei}{li} = \frac{1 - f}{1 - fei}$$

For such layer the ratio of expanded depth leitothe in expanded depth li is -

$$\frac{lei}{li} = \frac{1 - f}{1 - fei}$$

And total expansion then becomes

$$le = \sum lei = \sum \frac{li\ (1 - f)}{(1 - fei)}$$

If f is constant for all layers.

li = full depth l times the percentage P_i of diameter d_i.

di = an average diameter such that the geometric mean diameter of the upper and lower sieve sizes representing a factor f_i of the analysed sand.

Size of Sand d (cm)	Sand having d_{cm} or larger than the stated size %		P_i % of the sand fraction	$\frac{P_i}{d_i}$ Unstratified	$\frac{P_i}{d_i}$ Stratified
0.1	0				
0.2	1	0.15	1		
0.3	8	0.25	7		
0.4	28	0.35	20		

FILTER OPERATION AND MAINTENANCE

In practice the filter operation is generally incooperated in the normal water treatment operations. The way in which a particular filter operates depends entirely on the desired objectives. Some filteres may be designed to operate at high rates, some at low rate, some may just be roughing or polishing filters. For the desired objectives to be achieved, proper maintenance programme must be drawn. It is important that maximum precaution be taken to assure continuous operation and to maintain the water level above the sand. This is necessary to protect the layer of silt which builds up on the surface of the sand and the slime film which coats the sand grains near the top of the filter, as these deposits help considerably in decreasing the efficiency of filtration. This is usually in the case of slow sand filters. If it is not operated as indicated above, it may actually provide favourable breeding ground for bacteria, and as a result of this the total number of bacteria in the filtered water may be greater than that in the influent.

In the case of rapid sand filter, for its operation to be continuous and assumes uniform dimension regular back washing must be carried out.

Apart from the backwashing there are other important aspects which should be properly checked and maintained for effective operation to be achieved. These can be broadly classified as follows:

1. Filter troubles.
2. Filter Appurtenances.

1. Filter troubles

In any civil engineering project no matter its magnitude, there is bound to be some integrated troubles arising due to one cause or the other. Some of the causes may include climatic changes, errors during design or construction, chemical constituents of the soil of the site. In addition to these, filters may be subjected to other variety of ailments examples of which also include the cracking of the sand bed, formation of mud ball, plugging of portish of bed, jet action at the gravel-sand separation plane, sand boils and sand leakage into the under drainage.

In fact there are certain associated operating troubles which may become so great that subsequently the filter media and supporting gravel may have to be removed every two or three years, cleaned and reclassified and replaced in proper order.

Trouble of this nature usually accurs as a result of poor design and operation, particularly in adequate back-washing, possible means of measuring the relative dirtness of filter is the concentration of colour and or turbidity in the filtered water.

Badly clogged filters may be restored to usefulness by;

1. Scraping the sand and cleaning it in a sand washer.
2. Directing hose streams into the expanded bed.
3. Agitating the expanded bed by hand with the help of long-tined raker.
4. Adding detergent such as a 2 or 5% solution of caustic soda, draining it off through the filter bed to waste connection and wash bed with clean water.

Filter Appurtenances

These include both the manually, hydraulically, pneumatically or electrically operated sluice gates and valves on the influent, effluent drain and wash water lines, measuring devices such as venturi meters, rate controllers activated by a measuring device, loss of head and rate of flow gauges, sand expansion indicators, wash water controllers and indicators, operating tables and water sampling devices, water quality monitoring devices, sand ejectors and washers and wash water tanks.

For the proper operation of a rapid sand filter all what is mentioned above must be properly and adequately maintained.

In order to effect proper maintenance of filter and its appurtenances qualified operatives must be employed, the quality of the staff is better preferred to their quantity. Therefore among the operatives to be employed should include competent mechanics, fitters and plumbers. These workers can be selected out of the construction staff. They also must be given further training as to improve the group level of occupational efficiency. Training alone can not improve their competency, they must be given proper incentives such as good salaries, better housing accommodation as most water works are sited some distance away from the consumers or in the alternative be provided with better means of transport to and from working place, provide hotels and better dining area, good fringe benefits and cordial atmosphere must always prevail among all levels of the workers.

In addition the management must always keep adequate stock of spare parts as these must be required from time to time.

The Practical Preparation of Filter Media

The actual sampling was carried out on the only available stock stored just behind the concrete laboratory. For any sand to be successfully converted into filter media it must be thoroughly dried and cleaned, that is, free from either organic or inorganic contents. By simple physical test I found out that the sand did not contain either organic or inorganic matter. The test was carried out by simply rubbing a portion of the sand between my fingers and examined them to see whether there was any silt or organic matter left on them. But as far as that stock was concerned I could not see any dirt. But obviously the stock was wet as it was stored outside, therefore has been subjected to heavy rainfall from time to time as it was rainy season. In order to ensure thorough drying, a portion of the stock was spread on the laboratory floor for a period of at least one week. After drying then an analysis of the stock was carried out. That was done with the help of a set of British standard sieves available. The sieves were arranged in order of their mesh magnitude ranging from No. 7 down to the retainer as follows No. 7, No. 14, No. 25, No. 36, No. 52, No. 72, No. 100 and the retainer.

A portion of the dried sand was sifted through set of the British standard sieves by shaking them thoroughly within a stipulated time lapse of five minutes, with help of a standard electrically operated sieves shaker. After the elapse of the stipulated time of shaking. The portions retained on the successive sieves were weighed separately, starting with weighing of the portion retained on the pan or retainer. The successive portions held between successive or adjacent sieves were weighed. The cummulative of those weights were found and recorded (as shown on the lab sheet). The weights were converted into percentages by weight equal to or less than the size of separation of the overlaying sieve. The cummulative distribution curve was then plotted as shown on the particle distribution sheet.

For better results and also due to the limitation of supply of sand I have conducted three analysis on the same available stock. After comparing the results obtained from the separate analysis I have found that there was little variations in all respect. Those results were the actual ones I used to plot the particles distribution curves, these curves were found to be of identical nature as shown on the particles distribution sheet.

It has been discussed in the previous chapters that after successful analysis of a stock, the selection of grain sizes of a filter media is then commenced. This is based on two creteria, namely the effective sizes and *or* the *uniformity or non uniformity coefficient*. The **later** is the ratio of the ^{P}60 percentile P of the stock to the 10 percentile P_{10} of the same stock. Unfortunately the later creteria can not be employed to give better result with nature of the available sand, so I was left with no choice but to use the effective sizes method. It was also discussed and recommended in one of the previous chapters that the sizes of sand required to be used for a projected filter with better or higher efficiency as our creteria, should be between the sizes of .2mm to .4mm this grade of sand will provide little or no difference in efficiency even with different types of applied waters. From the stock analysis I carried out I found out that those grain sizes were retained between sieves No. 36 and No. 72 all the rest was either too coarse or too fine for the projected filter.

Since those sieves specified above gave the required effective sizes of the filter media, therefore in order to obtain a reasonable quantity of say 5 kilograms of the sand media sample, continuous sifting was carried out and collecting all sand which passed through

No. 25 sieve and retained on No. 72 sieve after elapse of each five minutes until the required quantity was found.

CONCLUSION

For all intent and purposes sand was found to be the common and most effective filter media among all the filter media throughout the world. It can be used on a large scale filtration in big water waters as well as small units for domestic purposes. If the prepared sample whose uniformity coefficient was between 2.25 and of effective sizes of between 0.2 - 0.4mm is used in a projected filter. It will be capable of removing large quantity of organic and inorganic matter. Among the organic matters that can be removed include cysts, parasites ova, cercariaes, bacteria and other similar large organisms. It can not effectively remove viruses because of their small sizes, they can easily pass through the sand bed as the pore spares or intertices of the bed are larger than the viruses. Some fine turbidity or cloudness may also be passed to the filtered water.

In order to make this media effective, the filter must be skill-fully operated. With proper utilization of the sand from the local sources, considerable amount of money will be saved by the Public Water

Works in this country, because when we look into every Water Board's budgets we can clearly see that except for the little amount spent on the local labour about 60 - 75% of them are spent outside this country on either spare parts, chemicals and or other appropriate items used in water works. Up to now most Water Works import sand for their filtration purposes.

In practice one can test the efficiency of a filter media with help of a model filter.

A simple filter can be constructed from a steel drum 60 cm (24 in.) in diameter and 75 cm (30 in.) high, with a container underneath to collect the filtered water. Drill a hole 2mm ($3''/32$) in diameter in the bottom of the drum to serve as the filter outlet. Place a few centimeters of small stones, about pea-size, in the bottom of the drum and fill to with in 10cm (4 in.) of the top with fine sand. Make a hole on the side of the drum just below the rim for an overflow, and do it connect a piece of pipe for an overflow line. It may be necessary to place a small disc on the surface of the sand under the inlet to prevent scouring of the sand. To operate the filter, keep a continuous flow of water running into the top, just sufficient to keep the filter filled, with a slight or minimum overflow. A filter of this dimensions should deliver one litre per minute (12 g.p.h.) of clear water if all is well. If this is not achieved something must have gone wrong more especially with sand. In fact this type of filter can be used as small domestic unit for an individual more especially in rural areas.

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SIEVE ANALYSIS OF SAND (WET/DRY SIEVING)

Total Weight of Dry Samples - 765.5 gm

SAMPLE NO. 1

B. S. Sieve size	Weight retained	Weight retained (cumulative)	Per Cent Retained
Riffled sample passing 3/16			
$\frac{1}{8}$ in.			
No. 7	134	1340	100
No.14	240.5	374.5	65.0
No.25	253.5	628.0	41
No.36	69.5	697.5	9.9
No.52	29.0	726.5	4.0
No.72	17.0	743.5	2.3
No.100	9.0	751.5	1.2
PAN	14.0	765.5	

SIEVE ANALYSIS OF SAND (DRY SIEVING)

Total weight of dry sample = 1692.2

SAMPLE NO. 2

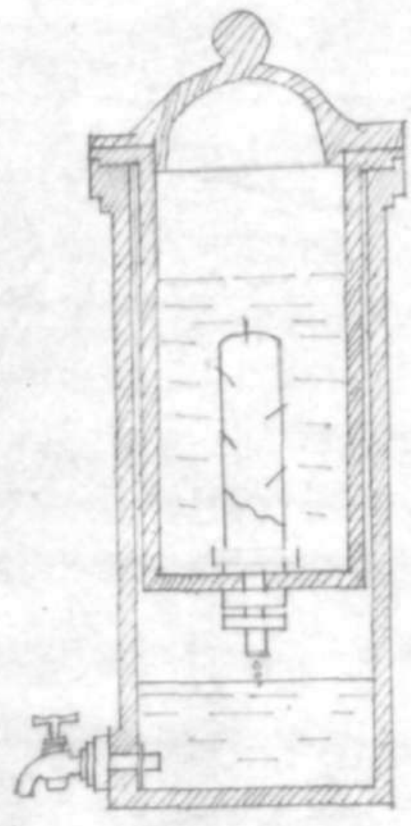
B. S. Sieve size	Weight retained	Weight retained (cumulative)	Per Cent Retained
Riffled sample passing 3/16			
$\frac{1}{8}$			
No.7	249.0	249.0	100
No.14	509.0	758.0	67.2
No.25	628.2	1386.2	45.4
No.36	155.0	1541.2	10.2
No.52	61.0	1602.2	3.8
No.72	39.0	1641.2	2.4
No.100	18.0	1659.2	1.1
PAN	33.0	1692.2	

SIEVE ANALYSIS OF SAND (DRY SIEVING)

Total weight of dry sample = 1497.2

SAMPLE NO. 3

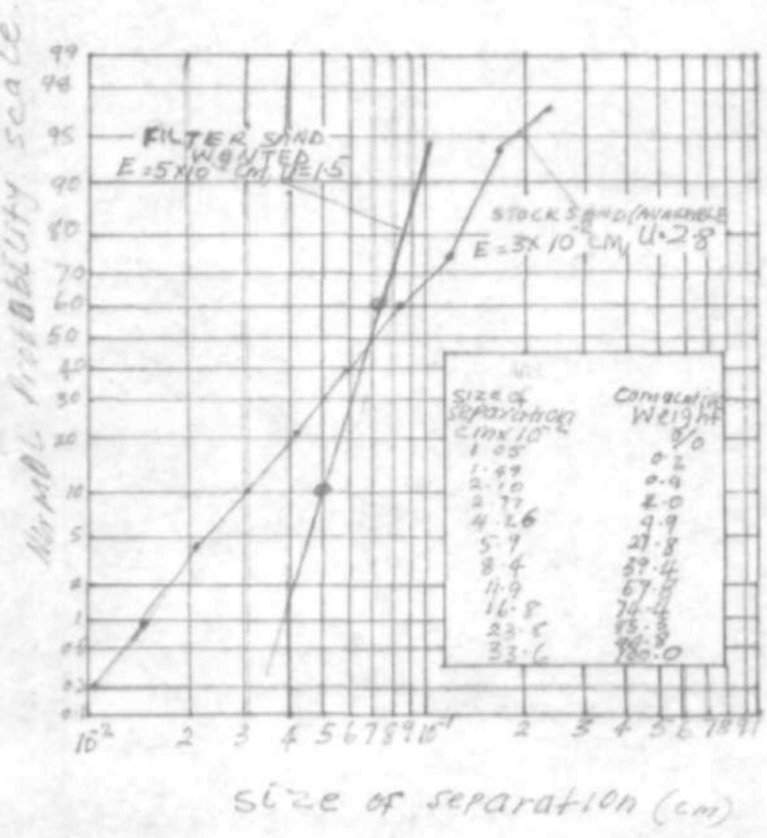
B. S. Sieve size	Weight retained	Weight retained (cumulative)	Per Cent Re-rained
Riffled sample passing 3 3/16			
$\frac{1}{8}$ in.			
No. 7	180	180	100
No.14	461.5	641.5	72
No.25	542.2	1183.7	45.8
No.36	147	1330.7	11
No.52	68	1398.7	4.76
No.72	47	1445.7	3.24
No.100	20	1465.7	1.36
PAN	31.5	1497.2	

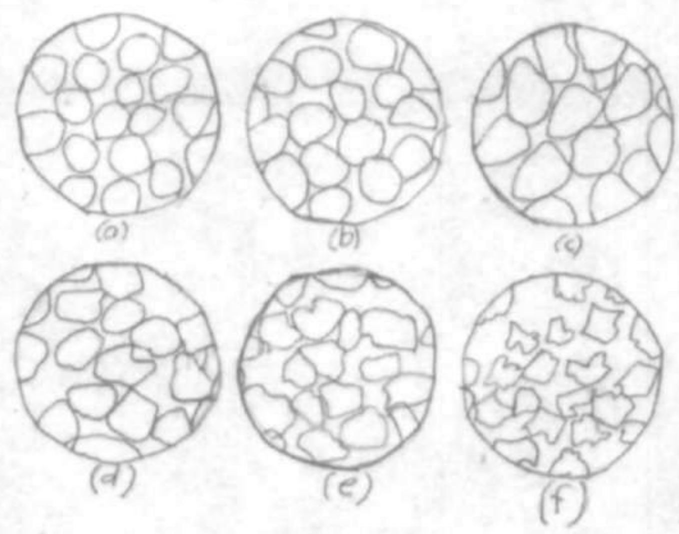


BERKEFELD FILTER

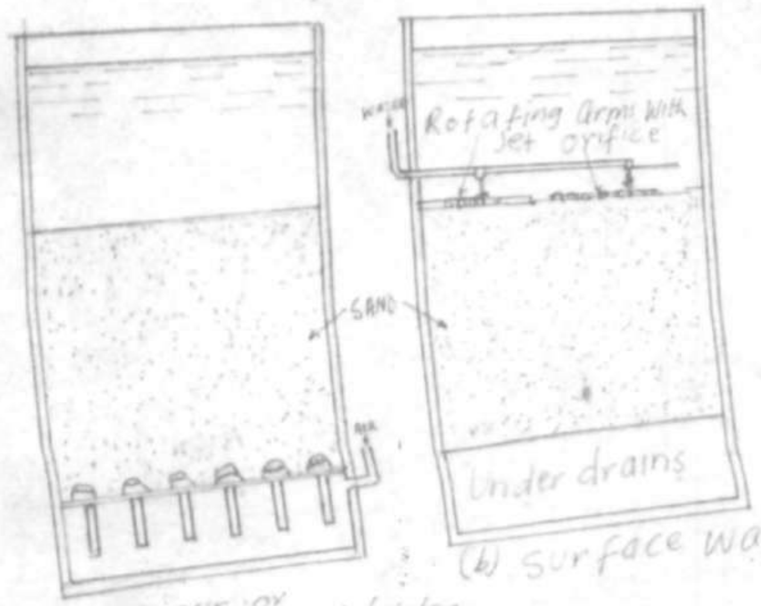
FIG. 1

GRAIN SIZE DISTRIBUTION OF STOCK AND REQUIRED SIZING OF A FILTER SAND





Sphericity and shape factors of granular (not flakelike) materials and typical ~~Pos~~ porosities with them in stratified rapid sand filter beds.



(a) Air scour or Combination air/water

(b) Surface wash

AUXILIARY SCOUR INTENSIFICATION IN RAPID FILTERS