

# SURFACE WATER PRETREATMENT USING FLOATING MEDIA FILTER

By C. Visvanathan,<sup>1</sup> D. R. I. B. Werellagama,<sup>2</sup> and R. Ben Aim<sup>3</sup>

**ABSTRACT:** Laboratory-scale experiments were conducted in contact flocculation filtration using a dual media filter operating in the upflow, saturated mode. The filter media was lighter than water; thus, the bed floated. Since coarse media remained at the bottom, the flow direction was upflow, which had the added advantage of the flow being in the direction of grain compression. Polypropylene and Polystyrene were the optimum combination of media, which due to their large density difference did not intermix even under severe agitation, thus eliminating the media intermixing problem common to dual media filters. The influent concentrations were kept constant and the flow velocity, and filter media size and shape were varied. The headloss variation along the filter, the influent quality of two filter layers, and the effluent quality were studied. Filter runs exceeding 40 h were achieved before reaching breakthrough at conventional rapid sand filtration rates. Floating media obtained turbidity removal per unit headloss in comparison to sand media, and floating media are proposed as a prefilter in surface-water filtration.

## INTRODUCTION

In surface water filtration, rapid sand filters are widely used for the removal of solids present in surface waters, precipitated hardness from lime-softened water, precipitated iron and manganese, and pathogens like *Giardia* and *Cryptosporidia*. These filters are popular for municipal applications due to their lower space requirement, higher production capacity, and higher flexibility in treating waters of different turbidities. The flow rate in a conventional rapid filter is in the 5–15 m<sup>3</sup>/m<sup>2</sup>·h range. The rapid filters conventionally treat water that has passed through several pretreatment steps like screening, rapid mixing, coagulation, flocculation, and sedimentation.

Depending on the raw water quality and treatment performance, a rapid sand filter has to be backwashed, usually after 24 hours of operation. If the production capacity of a rapid sand filter is increased, the clogging rate also increases, resulting in more frequent backwashing. In addition to the loss of production time, pure water has to be used for the backwashing operation. Rapid sand filtration would typically consume 1–6% (or more) of throughput for backwashing. To save this water as well as the operating time required for frequent backwashing operations, researchers in the last three decades have focused their attention on a wide range of process modifications such as upflow, biflow filtration, and mobile bed filtration to enhance the filter performance. Contact-flocculation filtration is one such modification, where water is directly applied to the filter only after screening, adding a coagulant, and rapid mixing. The clarification steps of flocculation and sedimentation occur within the bed itself. Advantages of this method are the removal of conventional sedimentation and flocculation steps and the reduced sludge-handling problems due to sludge being produced only during filter backwashing. The disadvantage is the shorter filter runs, resulting from the entire solids removal occurring within the filter bed itself.

Another research project on modifying the filter media

itself was the application of dual or multimedia filtration, which utilized various types of sand, crushed anthracite coal, diatomaceous earth, perlite and powdered or granular activated carbon, etc. as the filter media. Even these modified arrangements had the major drawback of frequent intermixing of filter media after backwashing. This intermixing in the interface zone resulted in rapid clogging of the filter, thereby reducing the interval between the backwashes. The floating media filter replaces the conventional sand media with floating polymeric resin media. The typical arrangement of a floating media filter is given in Fig. 1.

## Review of Research on Filtration Using Floating Media

There is some research on filter operation using floating media, but the development of this operation on a commercial scale was limited to wastewater-treatment applications. The Biostyr [Omnium de Traitments et de Valorisation (OTV) of France] or the upflow floating aerated biofilter has a filter bed of submerged and floating granular polystyrene. This wastewater-treatment process incorporates features of the classical biological aerated filter and of upflow filtration (Rogalla et al. 1992).

Rice et al. (1980) utilized an upflow filter using Filter-ag as the filter medium. Filter-ag is a commercially manufactured nonhydrous aluminum silicate with a 385–417 kg/m<sup>3</sup> density. The flow rate in this unit was 5.5 m<sup>3</sup>/m<sup>2</sup>·h. For raw water turbidity of 48 NTU, the filter unit had produced effluent of 1.5–2.0 NTU. Daniel and Garton (1969) experimented with various types of media, one of which was pelleted paraffin wax that floated. Even after 23 hours of operation the paraffin media had a turbidity removal efficiency around 80%. The Haberer process (Haberer 1972; Stukenburg and Hesby 1991)

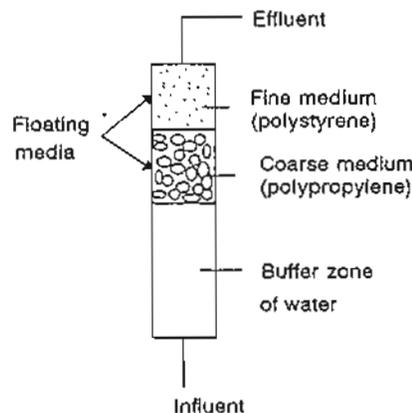


FIG. 1. Floating Media Filter Unit

<sup>1</sup>Assoc. Prof., Envir. Engrg. Program, Asian Inst. of Technol., GPO Box 2754, Bangkok, Thailand.

<sup>2</sup>Grad. Student, Hydr. Engrg. Div., Dept. of Civ. Engrg., Nagoya Univ., Furo-cho, Chikusa-ku, Nagoya 464-01, Japan.

<sup>3</sup>Prof., Université de Technologie de Compiègne, 60206 Compiègne, France.

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was an improved upflow filter in which backwashing of the filter is accomplished in a downward direction rather than upward, as practiced in other upflow filter designs. This used a 1.2 m deep monomedium bed of 1–3 mm foamed polystyrene (styrofoam) beads with a filtration rate of  $10 \text{ m}^3/\text{m}^2 \cdot \text{h}$ . Variations of this process have been patented as Refiltration flocculation (REFIFLOC) and powdered-activated carbon embedding filtration (PACEFILT) for wastewater treatment.

Haberer and Schmidt (1991) suggested that resin beads made of foamed polystyrene are better suited for an upflow filter than either polyethylene or polypropylene because of their lower density and substantially greater buoyancy in water. The polystyrene is inert and poses no health hazard. The beads should be as homogeneous as possible, and the optimal size depends on the application. During the backwash operation, the compact filter bed can be changed to a fluidized bed without the additional expenditure of energy by simply directing an intense rinsing stream downward, through the bed. Thus, the high backwash velocities required to fluidize the bed are obtained without a backwash water pump and air rinse.

In their upflow filter Haberer and Schmidt (1991) used foamed polystyrene beads 1–2 mm in size. The filter bed height was 1.0–1.5 m. They did not use a coagulant aid. Their experiments on a pilot filter with powder-activated carbon (PAC) coated polystyrene media showed that the smaller beads (0.9–1.3 mm) gave a consistently better organics-removal performance than the larger beads (size 1.6–2.5 mm).

The objective of the research reported here was to combine the advantages gained in floating media filters with those of dual media filtration and contact flocculation filtration. Research was carried out to find an optimum media combination for the floating media filter, which, while retaining the advantages of conventional dual media filtration, avoided its limitations.

## MATERIALS AND METHODS

### Experimental Setup

The schematic diagram of the experimental setup is shown in Fig. 2. The main components of the setup were the raw

water feeder system, chemical dosing system, filter column, and the filter media and backwash air/water feeder system.

The raw water, which was an artificial suspension of kaolin clay, was prepared in a 50 L tank. Once the required quality was ensured, the suspension was pumped from this tank to the raw water tank using a small centrifugal pump (kaolin concentration of  $88 \text{ mg/L} \approx 30 \text{ NTU}$  and mean particle size  $\approx 3.3 \mu\text{m}$  from the Salatip Kaolin Clay Co., Bangkok, Thailand). This artificial suspension of raw water was stored in a 290 L capacity raw water tank, which facilitated a 5 h filter run without replenishment at the maximum flow velocity used (15 m/h). Since most of the filter runs were much longer than 5 hours, the raw water tank was periodically replenished from the solution preparation tank. The raw water tank had a stirrer arrangement, which continuously stirred the suspension to prevent the suspended solids from settling.

A centrifugal pump fed raw water from the raw water tank to the constant head tank. The level was kept constant by an overflow arrangement, which recycled the excess water from the overhead tank back to the raw water tank.

A dose of  $20 \text{ mg/L}$  of alum [ $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$  from the Nonhaburi Alum Factory, Bangkok, Thailand) was added directly to the 50-L-solution preparation tank. The required dosage of cationic polymer (CatFloc T2, Calgon Corp., Pittsburgh, Pennsylvania) was introduced near the inlet of the filter, directly and continuously, to achieve contact flocculation. The use of polyelectrolyte was advocated by researchers (Adin and Rebhun 1974; Hutchison 1975; Quay 1991) because of the small floc volume characteristic offered by polyelectrolytes. The Catfloc T2 dosage for 30 NTU influent turbidity was established as  $0.5 \text{ mg/L}$  in jar test experiments.

The filter was a 1-m-high acrylic column with a 6.4 cm (0.064 m) internal diameter. The transparent column allowed observation of the media as the filtration process was in progress. The column had eight piezometer taps in the top 60 cm (0.6 m), with four piezometer ports for each media layer. These ports were placed at 7.5 cm (0.075 m) intervals. Even though there were five sampling ports in the apparatus, only one point (near the media interface) was used to measure the water quality.

The filter column was fixed vertically with raw turbid water

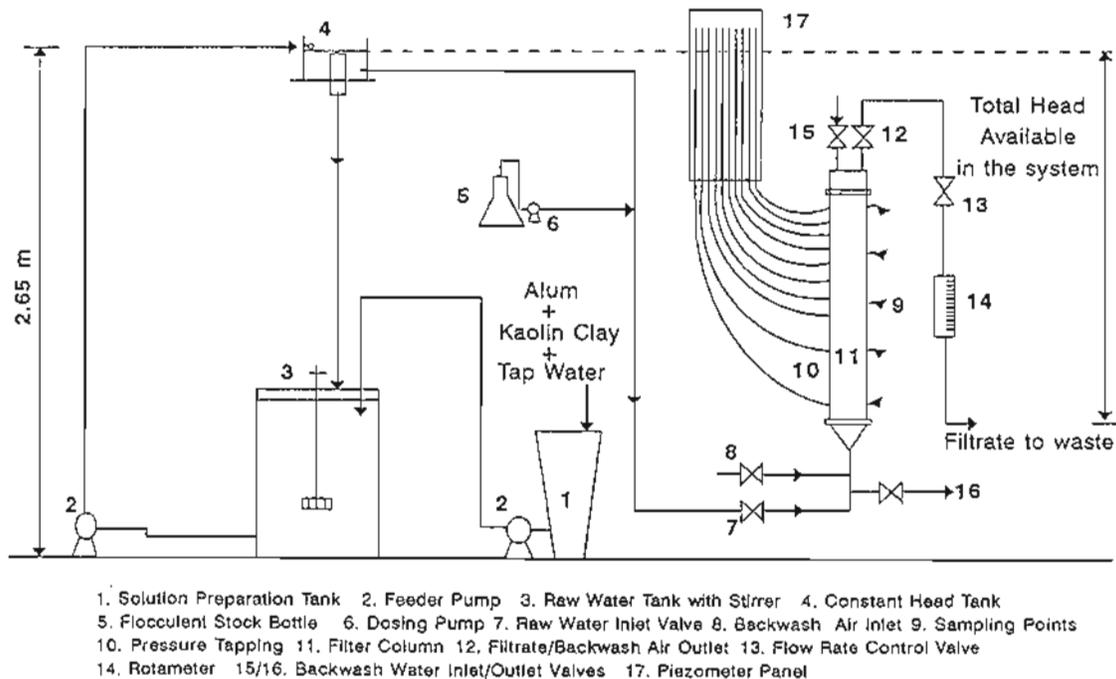


FIG. 2. Experimental Setup

entering from the bottom, for the upflow mode of operation. The filter bed was a 0.6-m-deep packed bed of granular media. It had a 30 cm fine media layer over a 30 cm coarse media layer for experiments with floating media. For this study the two media selected were granular polypropylene (PP) and polystyrene (PS), both of which have densities less than that of water. The filter needed an upper retaining mesh strong enough to withstand the buoyant forces exerted by PS. For the experiments with a sand medium the bed was 60 cm high and had a 1 mm geometric mean size. A bottom retaining mesh prevented the loss of media during dewatering of the filter.

A pinchcock clamp (valve 13, Fig. 2) was used to control the flow rate. The valve was frequently adjusted to maintain the required filtration rates of 15, 12.5, 10, 7.5, and 5 m/h.

### Filter Media

Polystyrene has a specific gravity of 0.05 and is inert and recyclable. It does not dissolve in hot water, sea water, weak acids, or inorganic hydroxides. Thus its chemical composition is not affected in a drinking-water-treatment operation. Polypropylene has a specific gravity of 0.903. The 2.57 mm PP was obtained by mechanically crushing and sieving the 3.66 mm media. The 3.66 mm PP was spherical while the 2.57 mm PP was angular. Spherical polystyrene (fine media) PS(s) was used in runs 18–30 and 38–42. Angular polystyrene (fine media) PS(a) was used in filter runs 31–37 and in 43. The resin media were visually observed after more than 1,000 hours of filter run and more than 50 backwashing cycles, but the grains were found to be whole and there were no visible fractions. The sand filter experiments were conducted by using sand with a geometric mean size of 1 mm, which resembles the mean size of sand used in a conventional rapid sand filter.

### Backwash System

The backwash procedure consisted of sending compressed air in the upflow direction at 100 m/h for 2 min followed by

water wash for 3 min at 50 m/h. For floating media, the water backwash was downward, achieving 65% expansion of the filter bed (30% expansion in PS and 100% expansion in PP). There was no intermixing of media during or after the backwash. For the sand medium, the water rinse was upflow too. After a filter run, valve 7 (Fig. 2) was closed and remained so until the backwash operation was complete. The backwash air entered from valve 8 and exited from valve 12. Valves 15 and 16 served either as inlet or outlet for the backwash water depending on the direction of backwash water flow.

## RESULTS AND ANALYSIS

The experiments to select an optimum media combination were carried out using media like polyethylene, polypropylene, and polystyrene of various sizes. Polyethylene was rejected as it intermixed with both PP and PS. The combination of PP and PS was selected because these media did not intermix even when agitated by compressed air and water. The PP (larger particles), being denser, stayed at the bottom of the floating bed.

### Summaries of Experimental Runs

The results of the experiments carried out for 30 NTU influent turbidity are presented in Table 1. Filter runs 20, 21, and 42 are the best runs for the floating media filter when considering the total volume of water treated per unit area of the filter. When runs 20 and 21 are compared, run 20 is considered better for the floating media filter due to its higher water production and the superior quality of water. Figs. 3 and 4 represent the typical effluent turbidity and headloss profiles. [Fig. 3 shows run 20, with a filtration velocity of 12.5 m/h and  $C_0 = 30$  NTU. The dual media consists of polystyrene 1.54 mm (s)/polypropylene 3.66 mm (s). Fig. 4 shows run 30, with a filtration velocity  $\approx 5$  m/h and  $C_0 = 30$  NTU. The dual media consists of polystyrene 1.54 mm (s)/polypropylene 3.66 mm (s).] The location of piezometer points are shown in Figs. 5–7.

TABLE 1. Summary of Experimental Results on 30 NTU Runs

Media (1)	Run number (2)	Flow velocity (m/h) (3)	Breakthrough time (h) (4)	Lowest NTU achieved (5)	Maximum headloss at breakthrough (m) (6)	Reason for termination of run (7)	Headloss distribution (%) (8)	Water production (m <sup>3</sup> /m <sup>2</sup> ) (9)
PP <sup>a</sup> 3.66 mm PS <sup>a</sup> 1.54 mm	19	15	8.5	7	0.35	Turbidity breakthrough	PS = 66 PP = 34	128
	20	12.5	22.8	4.5	1.1	Turbidity breakthrough	PS = 82 PP = 18	285
	21	10	27.5	4.7	1.05	Turbidity breakthrough	PS = 82 PP = 18	275
	22	7.5	22.1	5.5	0.65	Turbidity breakthrough	PS = 76 PP = 24	166
	30	5	More than 40	2.7		Terminal headloss at 40 hours	PS = 67 PP = 33	200
PP <sup>b</sup> 2.57 mm PS <sup>a</sup> 1.54 mm	39	12.5	7	3.1	0.2	Terminal headloss	PS = 74 PP = 26	88
	40	10	15	1.4	0.45	Terminal headloss	PS = 79 PP = 21	150
	41	7.5	28	2.5	0.75	Terminal headloss	PS = 72 PP = 28	210
	42	5	More than 41.5	1.5		Headloss at 41.5 hrs was only 97 cm	PS = 68 PP = 32	More than 208
Silica sand <sup>b</sup> 1 mm	45	15	13	0.55		Terminal headloss	—	195
	46	5	More than 23	0.15		Terminal headloss	—	115
PP <sup>b</sup> 2.57 mm PS <sup>b</sup> 1.54 mm	43	5	28	0.81	0.55	Turbidity breakthrough	PS = 77 PP = 23	140

<sup>a</sup>Spherical media.

<sup>b</sup>Angular media.

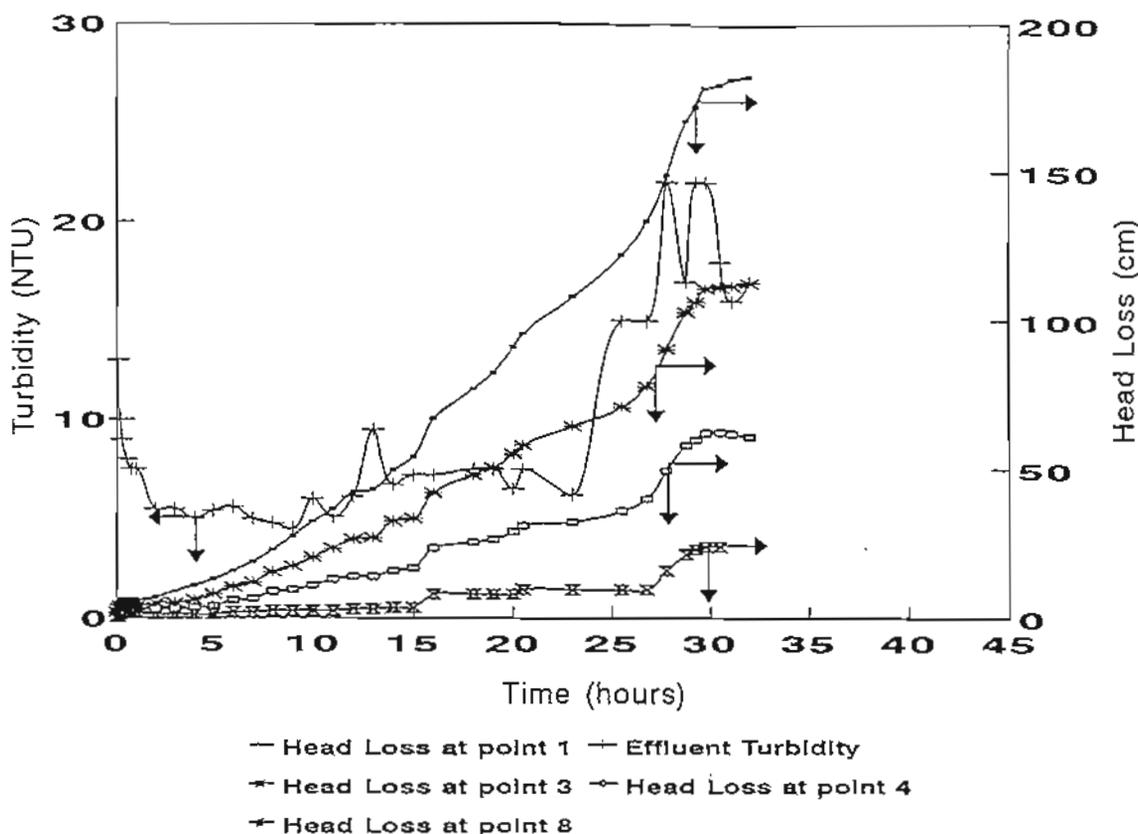


FIG. 3. Effluent Turbidity and Headloss Profile

#### Headloss Development and Breakthrough Behavior

As the clean bed headloss is a function of flow velocity, higher initial headlosses were observed for higher filtration velocities. The initial headlosses for the five filtration velocities used in this series of experiments are shown in Table 2.

For a threefold increase in the flow rate, the initial headloss ( $\Delta H_0$ ) in the floating media filter has increased sixfold. For twofold increases in velocity (5–10 m/h and 7.5–15 m/h), the average value of the initial headloss has increased three- and fourfold. This indicates a correlation approximating  $\Delta H_0 \propto v^{1.6}$ . Shea et al. (1971) reported a similar phenomenon (non-linear relation between initial headloss and rate of filtration) for sand filters operating in contact-flocculation filtration mode. Since the entry losses remain constant for a given constant filtration velocity, the subsequent increase of head during a filter run is due to the retention of particles. The particles retained by the media aid in entrapping more particles.

The headloss development along the filter is presented in Figs. 5, 6, and 7. The ordinates show the position of the piezometer tapping points in the filter and the abscissas show the headloss. Piezometer points 1–4 were connected to the fine (PS) medium and piezometer points 5–8 were connected to the coarse medium. Piezometer points 5–10 were connected to the sand medium. The curves for dual media (floating media) filter show a characteristic curve, which is easily distinguished from the curve for sand. Similar curves have been obtained for dual media filters employing sand and anthracite or two types of sands. The shape of this curve is determined by the media size and the ability of the media to capture particles. The curves for dual media filter runs show a rapid increase of headloss as the interface of the coarse and fine media layers is passed.

For most of the (dual media) filter runs the head development within the coarse media layer (PP) was linear, whereas the fine media layer showed exponential headloss develop-

ment. According to Shea et al. (1971), media zones that exhibit a large slope in piezometric head profiles are zones where concentrated flocs accumulation occurs. From the higher headloss in the fine media it can be stated that most of the removal occurs in the fine media layer. The headloss development in the coarse media was linear even after 40 hours of filter runs.

Considering the fact that a slight shortening of the filter bed (about 1.5%) was observed when the filter runs exceeded 30 hours of operation, the exponential headloss curves may also be due to the partially fluidized media matrix allowing the deposited material to be compressed.

Considering run 20 (Fig. 3), it is observed that turbidity of the filtrate was about 6 NTU in the first 23.5 hours after which the breakthrough occurs. The headloss is mainly concentrated in the PS layer, reaching about 1 m at the breakthrough.

The headloss development for floating media is at a much slower rate than that for sand. The possible causes for this are discussed later in this paper.

#### Effect of Physical Parameters

##### Filtration Rate

One media combination (PP of 3.66 mm and spherical PS 1.54 mm) gave reasonably good filtrate and higher water production rates for filtration rates 10 and 12.5 m/h. Both sand and floating media performed well at filtration rates lower than 7.5 m/h, with 5 m/h producing more water of better effluent quality at a lower headloss. This filtration rate is comparable with the filtration rate of a conventional rapid sand filter.

Since the higher filtration velocities push the particles deeper into the bed, the bed height of 60 cm utilized in this series of experiments might not have been sufficient to retain par-

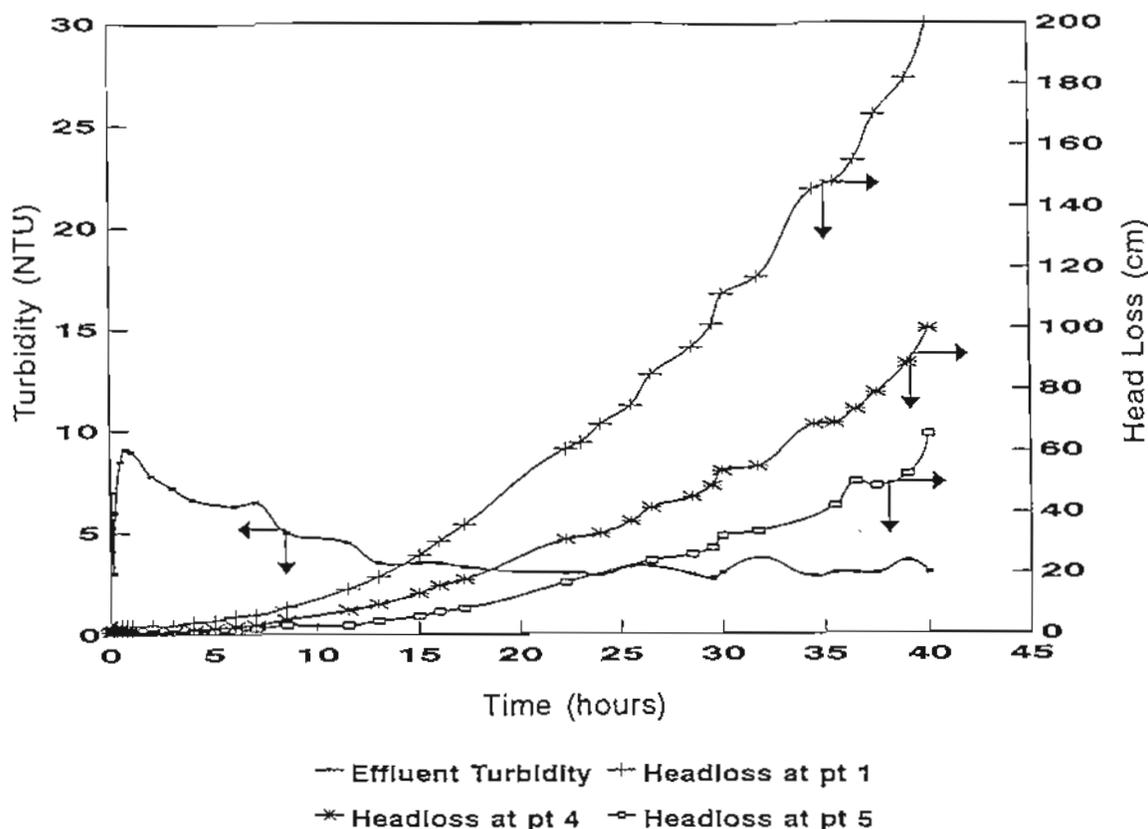


FIG. 4. Effluent Turbidity and Headloss Profile

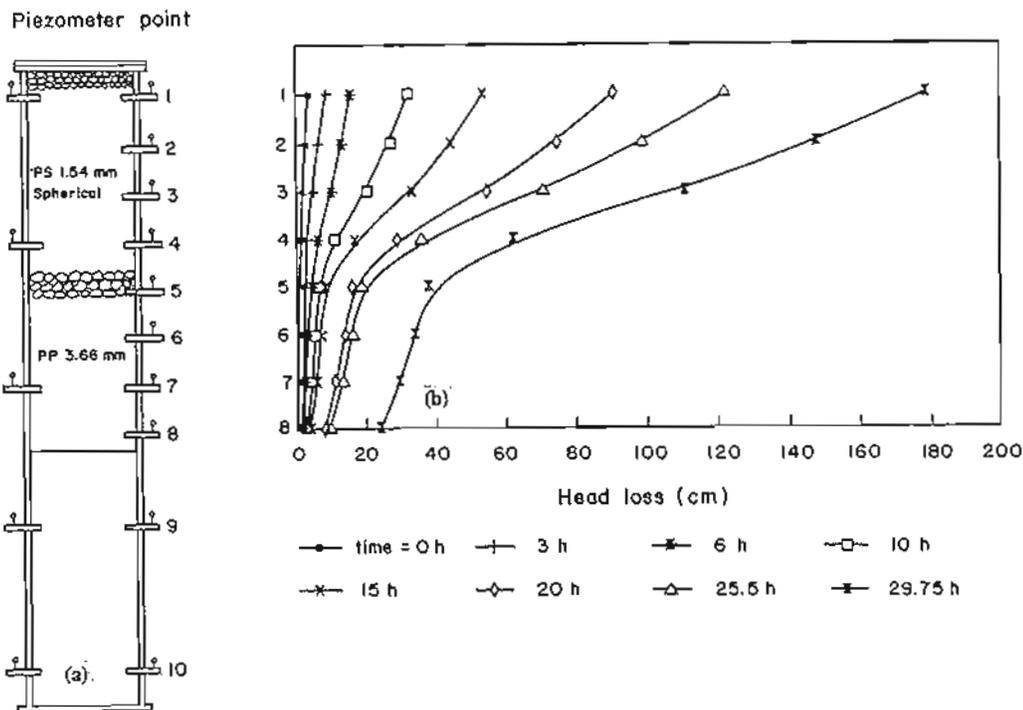


FIG. 5. Headloss Variation along Filter Bed at Given Time (Run 20,  $C_0 = 30$  NTU, Filtration Velocity = 12.5 m/h)

ticles at higher velocities. Studies are currently being carried out in a pilot filter using a 1-m high bed.

#### Media Size

Fig. 8 shows the results of two runs when two different sizes of coarse media were compared. The fine medium was a 1.54 mm spherical polystyrene. Better results were obtained

with a smaller coarse medium. Run 42 produced a better quality effluent with less headloss development, which proves that the particle capture by fine media was much less. This shows that the 2.57 mm coarse media was more successful in particle capture than the 3.66 mm coarse media. Retention of particles by coarse media has caused a lower additional headloss than retention by fine media. Clark et al. (1992) reported a similar phenomenon for experiments with sand media.

Piezometer point

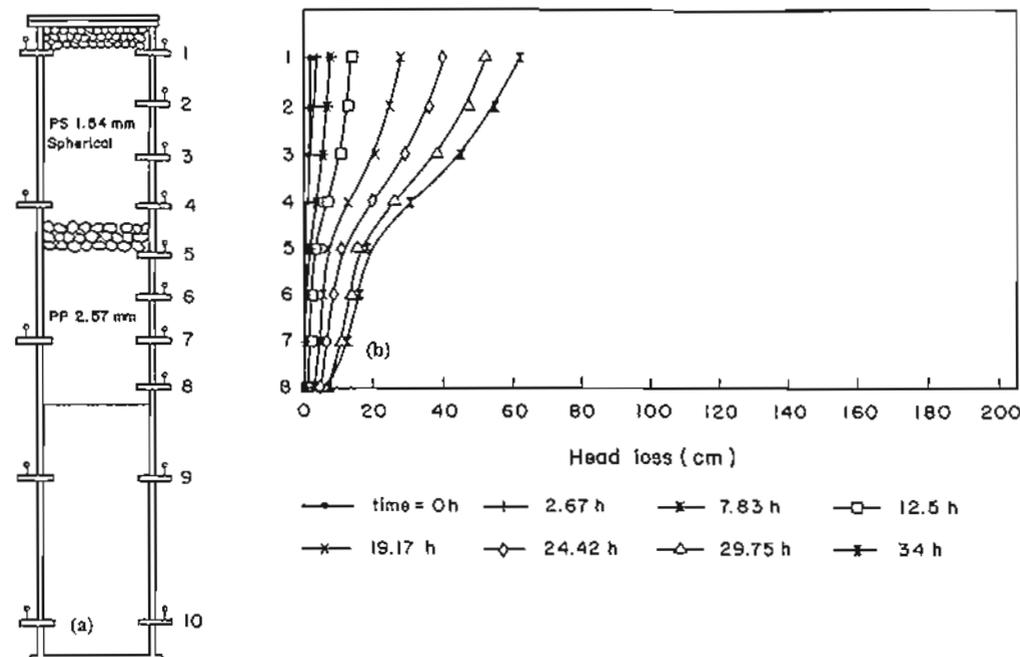


FIG. 6. Headloss Variation along Filter Bed at Given Time (Run 42,  $C_0 = 30$  NTU, Filtration Velocity = 5 m/h)

Piezometer point

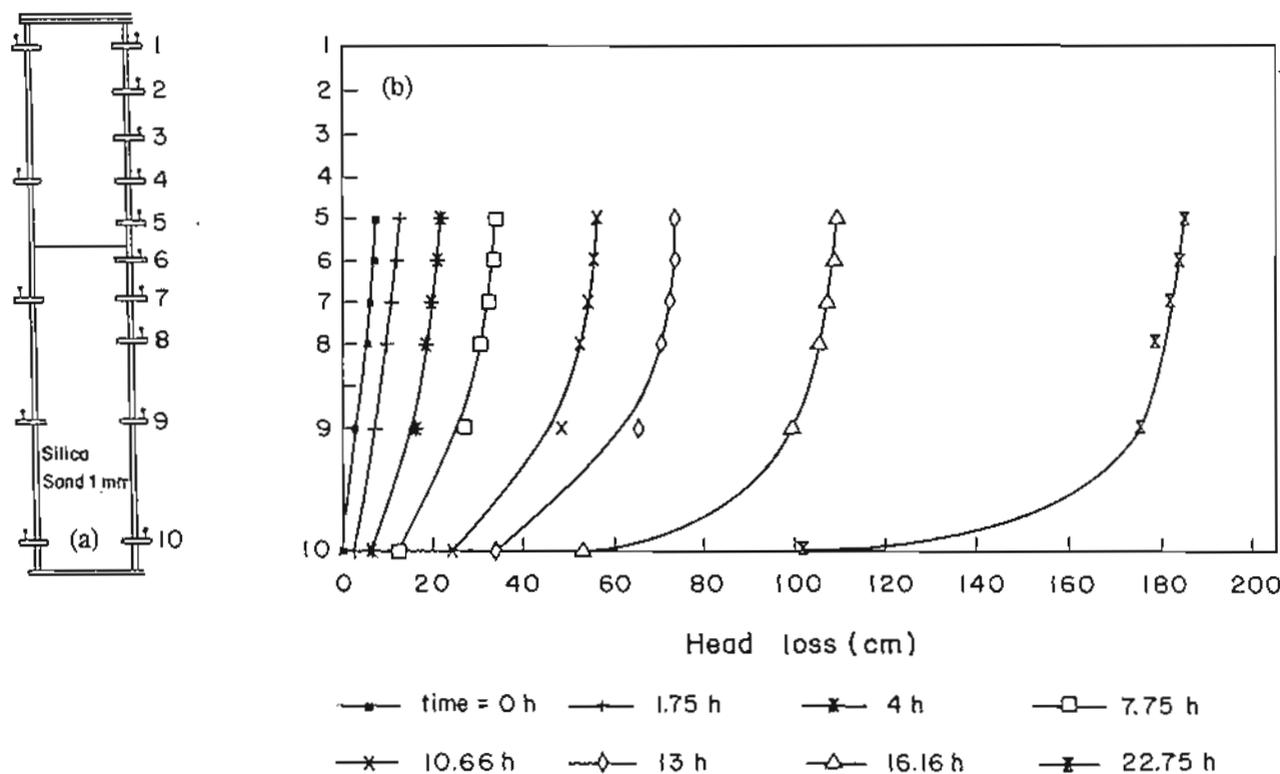


FIG. 7. Headloss Variation along Filter Bed at Given Time (Run 46,  $C_0 = 30$  NTU, Filtration Velocity = 5 m/h)

### Media Shape

When angular-shaped PS was used as a fine media, the headloss buildup was more rapid than that for spherical PS. The effluent turbidity was also relatively better for spherical media. A typical result is shown in Fig. 9, where runs 43 (angular PS) and 42 (spherical PS) are compared (Table 1). (In Fig.

9, filtration velocity = 5 m/h,  $C_0 = 30$  NTU, PP = 2.57 mm, and PS = 1.54 mm.) These experimental results reveal that spherical polystyrene media performs better than angular media. Considering water production and headloss development, the quality of the angular media filter was better up to 15 hours of operation.

TABLE 2. Initial Headlosses for Different Filtration Velocities

Flow rate (m/h) (1)	Average value of initial headloss (cm) (2)
15.0	25
12.5	17
10.0	12
7.5	6
5.0	4

**Backwashing**

In floating media filter, the airflow agitated the coarser medium (PP) very well while the PS beads did not agitate. The flocs being pushed down from the fine media due to the airflow was apparent from the change in the color of the PS bed (Werellagama 1993). Using this phenomenon, a backwash system, which provides a small amount of water simultaneously with the air backwash, would be able to achieve complete cleaning of the bed, without using a large amount of water. This backwash water can be sent from the bottom or laterally from the walls.

Both floating media agitated very well in the countercurrent water rinse. In a practical situation the volume of filtered water stored above the filter bed could be utilized for backwashing.

**Experiments With Sand Medium**

The summary of the filter runs using silica sand are shown in Table 1. These comparative runs with a monomedium bed of silica sand gave very good filtrate quality as expected, but the runs were much shorter, reaching the terminal headloss quickly. For a 15 m/h filtration rate, even the sand did not perform well with partial fluidization occurring in the bottom

5 cm, after 6 hours of operation. For a sand medium cocurrent (i.e., upflow), backwash with water (preceded by air) seemed the better method of backwashing. The additional advantage is that the media naturally graded itself to coarse to fine arrangement after the water flow was stopped.

The best run with the floating media is compared with the best run with sand media in Fig. 10. The headloss values used are the maximum headloss for each case. The amount of solids removed per unit area of the filter is proportional to the area above the effluent concentration ( $C_t$ ) curve and below the influent ( $C_0$ ) value. Graphically, this can be obtained from the discretized effluent curve by the following formula:

$$\sum_{\Delta t_i} v(C_0 - C_t) \cdot \Delta t_i$$

where ( $C_0 - C_t$ ) = turbidity retained by the filter (in NTU);  $\Delta t_i$  = time interval (in h); and  $v$  = filtration velocity (in m/h).

The filter runs with sand gave a relatively better product water quality but the headloss development was much faster than in floating media. One reason for this is the larger size of the floating media. In addition, the dual media arrangement and the partially fluidized nature of the floating bed allowed the fine flocs to penetrate deeper into the bed and, thereby, utilize the filter bed more efficiently, resulting in a lower headloss. This phenomenon was clearly demonstrated in Figs. 5-7. Another reason for the phenomenon is that the sand bed was in contact with the water inlet as compared to the bottom of the floating bed, which was 40 cm above the water inlet. The additional contact time available for the floating filter ensured the formation of larger flocculation, which could be retained in the coarse floating media. Some larger flocculations were observed to settle without reaching the floating media and formed a thin deposition on the lower mesh.

The advancement of the filtration front was observed for

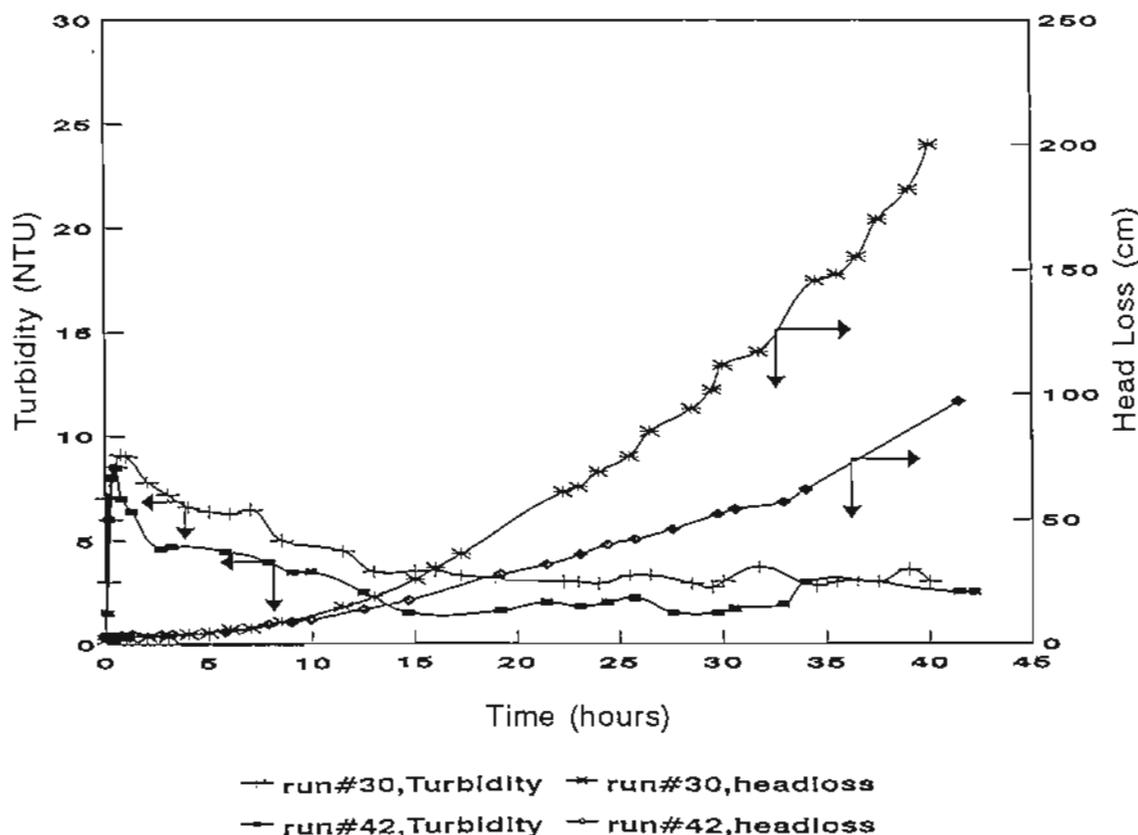


FIG. 8. Comparison of Two Sizes of Coarse Media (Run 30: PS 1.54 mm, PP 3.66 mm, Run 42: PS 1.54 mm, PP 2.57 mm, Filtration Velocity = 5 m/h,  $C_0 = 30$  NTU)

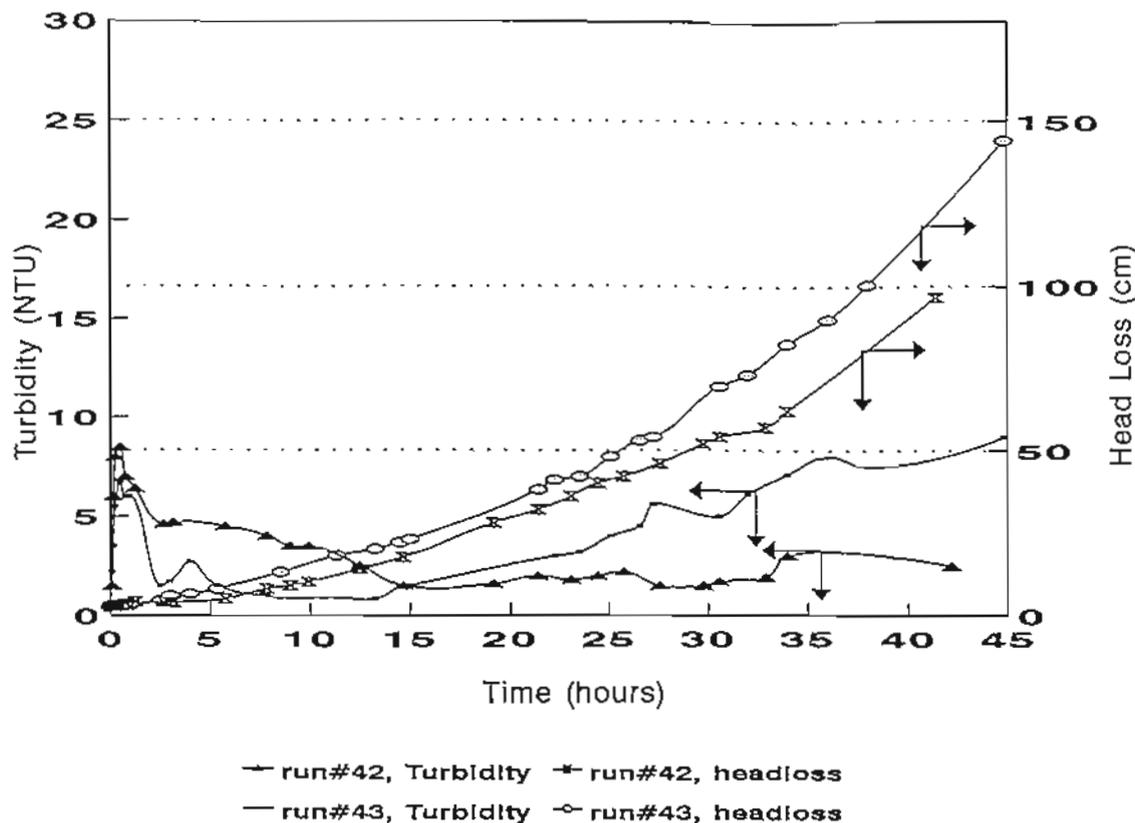


FIG. 9. Comparison of Concentration and Headloss Profile for Angular and Spherical Fine Media

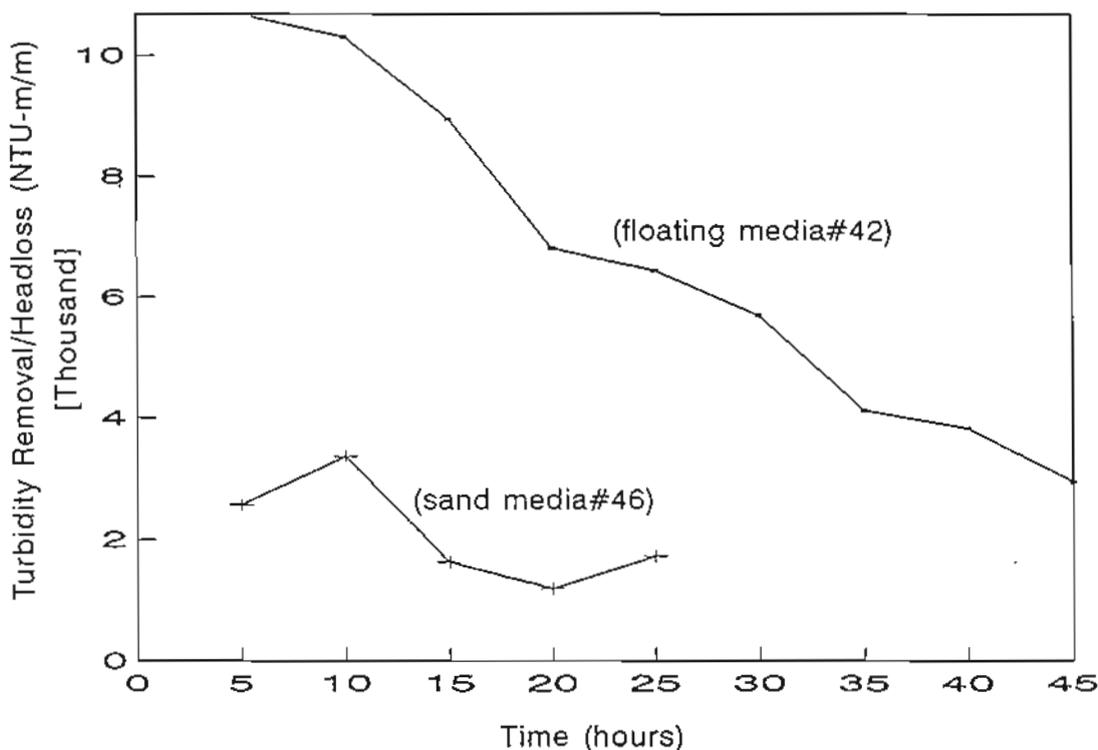


FIG. 10. Comparison of Best Runs for Floating Media and Sand (Run 42: Floating Media, Run 46: Sand)

runs with sand media. For synthetic media, the advance of a front was not noticeable, but a change in color from white to brown was noticeable as the run progressed. The color change was even for the whole bed, indicating flocculation retention throughout the filter bed. This result shows that the floating media filter uses the filter bed more efficiently than the sand medium filters.

The energy required to resuspend the solids in the floating bed is much less than the energy required for a sand bed. Therefore, the floating media filter can be backwashed with compressed air and a little amount of water. Alternatively, a downflow water rinse can backwash the filter to the same degree. The sand medium used the same amount of backwash air as floating media but needed a relatively larger amount

of water for backwashing. Although the floating media could be backwashed with water alone, the sand always needed air to break up the piston effect. Diaper and Ives (1965) attributed the piston effect seen in the upflow wash of sand to the arching effect due to the clogged media forming an impervious barrier. Considering the buoyant nature and the low affinity of the floating media particles to each other, the formation of an impervious barrier due to clogged media in the floating media filter is not possible.

Filter ripening performance was compared considering the time taken to attain an effluent turbidity value of 5 NTU. The sand filter runs for 5 m/h filtration velocity ripened within 15 min of operation, and the volume of water produced up to ripening was approximately 1.2 m<sup>3</sup>/m<sup>2</sup>. For 5 m/h runs with synthetic media (e.g., runs 30, 42, and 43) the filter ripening took 9, 2, and 1 h, respectively, producing 45, 10, and 5 m<sup>3</sup>/m<sup>2</sup> up to ripening. Quick filter ripening for synthetic media was observed in filter runs 39 (12.5 m/h), 41, 34, and 18 (the last three with 7.5 m/h filtration velocity), which produced 3, 1.9, 1.3, and 1.3 m<sup>3</sup>/m<sup>2</sup> of water, respectively, up to ripening. In a practical operation the product water during the ripening period can either be recycled or wasted, but neither one is an attractive solution. Thus, the filter operation has to be optimized to undergo ripening with the minimum loss of water. Since the filter ripened quickly for the higher (7.5 m/h and 12.5 m/h) flow rates, operating first at a high rate and then gradually returning to the 5 m/h rate may bring in faster ripening, even in runs with a 5 m/h filtration velocity.

Adin and Rebhun (1974) observed that coating the media with flocculent increases the chances of efficient attachment. Several researchers (Clark et al. 1992; Haney and Steimle 1974) reported that distilled water was pumped with a polymer injection prior to their filtration experiments. The media was coated with flocculant for a 30–60 min period to ensure that any ripening observed in the experiments were due to particles being captured in the media and not because of changes in the surface chemistry of the media, caused by the polymer after the experiment began. Shea et al. (1971) indicated that the addition of 20 mg/L of alum would provide the necessary coating for the media, enabling it to collect the incoming flocculations effectively. Since 20 mg/L of alum was added to the feed solution, coating of the media with polymer was not attempted in this series of experiments. However, coating of the media with polymer may also provide an answer to the problem of hastening the filter-ripening period.

## SUMMARY OF FINDINGS

The synthetic floating media filter is a relatively innovative technology, which can be effectively used as a roughing filter for surface water treatment. The fact that the floating media filter omits the pretreatment steps of sedimentation and flocculation complements its use as a prefilter. The initial series of laboratory-scale studies reveal that floating media filters can provide higher turbidity removal per unit headloss, compared with sand filters, at conventional rapid sand filtration rates. Nevertheless, as the effluent quality did not meet the potable water requirement, in terms of effluent NTU, this filter system, at the current stage of development, does not appear to be a promising alternative to conventional rapid filters.

The use of synthetic floating media will aid in the cheaper design and operation of filters because of the media's lower weight and moderate cost.

Of the media combinations studied in this series of experiments, the best results were obtained with 2.57 mm PP and 1.54 mm spherical PS operating at 5 m/h, and 3.66 mm PP and 1.54 mm spherical PS operating at 12.5 m/h; both in terms of filtrate production per unit area and lower headloss. The turbidity removals obtainable in these runs were around 90%.

In this filter, the fine to coarse arrangement allowed the removal of flocculations along the depth of the filter. The floating media filter eliminated the problem of media intermixing while retaining the inherent advantage of dual media filters, namely, lower headloss and higher retention capacity of flocs.

In the floating bed filter, most of the floc removal occurs in the fine (polystyrene) media layers. The concentration of headloss in the polystyrene indicates that the porosity has changed in this layer.

When media of two sizes were compared as the coarse medium, the smaller sized coarse medium gave a better floc removal. Spherical fine media performs better than the angular fine media, both in terms of water production and lower headloss, while initial product quality using angular media is superior.

Since the floating bed filter has a buffer zone of water between the water inlet and the bottom of the bed, bed disturbances due to uneven flow distribution may not occur as in upflow sand filters. This buffer zone also eliminates the need for elaborate underdrain systems in a practical application, which will help reduce the capital, operation, and maintenance costs.

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## APPENDIX II. NOTATION

The following symbols are used in this paper:

- $C_i$  = Effluent turbidity in the  $i$ th time interval (NTU);  
 $C_0$  = initial turbidity (NTU);  
 $\Delta H_0$  = initial headloss (m);  
 $\Delta t_i$  =  $i$ th time interval (h); and  
 $v$  = filtration velocity (m/h).