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WATER AND SANITATION FOR ALL: PARTNERSHIPS AND INNOVATIONS

Filtration with a natural coagulant

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RIVER WATER DRAWN for human consumption in many developing countries can be highly turbid particularly in the wet season. Such waters can be treated effectively using conventional treatment systems incorporating coagulation, flocculation, solid-liquid separation and disinfection. Low turbidity waters, as may be experienced during the dry season, are inherently difficult to treat due, primarily, to the relatively low concentration of suspended particles. Under such circumstances the use of a conventional treatment train can result in the inefficient use of excessive coagulant to provide effective treatment. Alternatives that may be considered for the treatment of low turbidity waters include slow sand filtration (SSF) and direct filtration (DF). SSF provides effective treatment at low filtration rates (generally 0.2 to 0.4m/h). As such, SSF has the disadvantage of requiring an extensive land area to provide significant quantities of treated water. DF involves the formation of floc prior to high rate filtration (generally up to 15m/h). The primary disadvantage of DF is the requirement for a flocculation stage and backwashing facilities can involve significant construction and maintenance costs. The use of contact flocculation filtration (CFF), a process whereby coagulant is introduced directly to the raw water inflow immediately prior to the filter inlet, is considered to be a viable single stage treatment alternative. With CFF flocculation and deposition occur entirely within the sand bed. A flocculation stage is not required, consequently there is a reduction in construction and operational costs over DF, suggesting that such a process may be a viable option for developing countries.

The CFF process is under investigation at Leicester University in the UK using material of plant origin as a coagulant. The natural coagulant is obtained from the seeds of the pantropical tree *Moringa oleifera* Lam (*M.oleifera*). This tree is native to Northern India, Pakistan and Afghanistan, but is now widely cultivated throughout the tropics. It can be grown from seeds or cuttings in poor soils with minimal horticultural attention and watering. The tree can grow up to 4 metres and commence fruiting within the first year (Folkard *et al*, 1993). It is a multipurpose provider, with the tree, seeds, flowers, seed oil and leaves used variously (Folkard *et al*, 1995). For water treatment applications the seed pods are allowed to dry naturally on the tree prior to harvesting. The seeds are then removed from the shells, crushed into a fine powder and sieved. When mixed with water, the seed powder yields low molecular weight, highly basic proteins which act in a similar manner to that of synthetic cationic polyelectrolytes.

Laboratory studies

Laboratory studies were conducted on model low turbidity waters using laboratory scale sand filters in a CFF configuration. The rig consists of two perspex columns of internal diameter 100mm. Diametrically opposed connections for piezometeric headloss measurement and turbidity sample extraction are located at intervals along the column to enable monitoring of the removal process within the filter bed. The filter media used was silica sand. In order to establish performance characteristics laboratory studies were carried out using a model raw water consisting of Kaolin clay in deionised water. The use of such a model water allows for direct comparisons between experimental runs without variations in raw water quality that may be encountered when using a natural water (McCooke and J.R. 1978). *M.oleifera* seed solutions were prepared using a previously established method and dosed as a 1 per cent solution (Folkard *et al*, 1996). The effectiveness of the filtration process was measured in terms of final water turbidity, headloss development and volume of treated water produced. Experimental runs were terminated when treated water turbidity exceeded the World Health Organization guideline value for potable water of 5 NTU (WHO,1993) or headloss exceeded 2.4m (Adin and Rebhun, 1974).

Results

Five raw water turbidities were examined viz.: 10, 20, 35, 50 and 75 NTU, at filtration rates of 5, 10 and 20 m/hour. The bed depths considered were 0.7 and 1.2 metres. Two sand grain sizes were compared for effectiveness as filter media. The smaller classified as British Standard (BS) mesh size 16/30 (nominal size range 0.50-1.00mm), the larger as BS mesh size 10/18 (nominal size range 0.85-1.70mm). The optimum dose was determined by conducting a series of filter runs to termination. A summary of the main results is presented in Table 1.

The effect of sand grain size

Increasing the size of the sand grains used as the filter media had two major effects. Firstly a reduction in filtrate quality and secondly a reduction in the rate of headloss development across the filter bed. Figures 1 and 2 show turbidity removal and headloss development with the two sand sizes at an initial turbidity of 50 NTU. In both cases turbidity breakthrough was the terminating factor for the filter run. Consequently the filter bed with the smaller sand size was more effective than the larger sand, producing 54

Table 1. Summary of the main results obtained from the laboratory scale filter

Initial Turbidity (NTU)	Sand Size Range (mm)	Sand Bed Depth (cm)	Filtration Rate (m/hour)	Seed Dose mg/L	Total Output (m^3/m^2) *
75	0.50-1.00	70	10	5	20
75	0.50-1.00	70	5	25	70
75	0.50-1.00	120	10	50	40
75	0.50-1.00	120	5	25	78
75	0.85-1.70	70	10	50	10
75	0.85-1.70	120	10	25	45
75	0.85-1.70	120	5	25	72
50	0.50-1.00	70	20	35	17
50	0.50-1.00	70	10	25	54
50	0.50-1.00	70	5	25	46
50	0.50-1.00	120	10	25	72
50	0.85-1.70	70	20	25	25
50	0.85-1.70	70	10	25	33
50	0.85-1.70	120	10	25	33
35	0.50-1.00	70	20	25	55
35	0.50-1.00	70	10	25	80
35	0.50-1.00	70	5	15	150
35	0.50-1.00	120	10	25	80
35	0.85-1.70	70	10	15	50
35	0.85-1.70	70	5	10	154
35	0.85-1.70	120	10	25	80
20	0.50-1.00	70	20	25	10
20	0.50-1.00	70	10	20	134
20	0.50-1.00	70	5	10	145
20	0.85-1.70	70	20	20	129
20	0.85-1.70	70	10	20	134
10	0.50-1.00	70	20	10	116
10	0.50-1.00	70	10	10	224
10	0.50-1.00	70	5	15	242
10	0.85-1.70	70	5	15	331

* Total output for an equivalent filter of surface area $1m^2$

m^3/m^2 as compared to 33 m^3/m^2. Note that the output is expressed as that volume of water passing through a unit area of the filter and provides a more effective comparison of experimental runs at different filtration rates (Adin and Rebhun, 1974).

However, for an initial turbidity of 10 NTU (Figures 3 and 4), the reduction in filtrate quality produced from the filter with the larger sand grain size was less significant. The reduction in headloss development was of greater significance, since this was the termination factor for the filter run. The bed with the smaller sand grain size produced 242 m^3/m^2 as compared to 331 m^3/m^2 from the bed with the larger grain size - an increase of 37 per cent of useful throughput.

The effect of higher filtration rates

Figure 5 shows the effect of increasing filtration rate on filtrate quality and output for experimental runs carried out at an initial turbidity of 35 NTU. With reference to Figure 5 and Table 1 it can be seen that in general an increase in filtration rate reduces filtrate quality and output.

Increasing the filtration rate increases the rate at which material is deposited, as shown by the shorter working in stage, however, this has the additional effect of increasing the interpore shear forces. If the shear forces exceed the attachment forces the result will be a higher degree of breakoff from the surface of the filter bed media. The net result is that material is removed from suspension at a reduced level, as indicated by the reduction in filtrate quality.

The effect of increasing bed depth

From Figure 6 and Table 1 it can be seen that increasing the bed depth from 0.7 to 1.2m improves filter performance in terms of filtrate quality and volume output. It was found that the reduced performance (in terms of filtrate quality) of the filter bed of larger sand size could be counteracted by using deeper beds, whilst still maintaining the benefit of lower headloss development. Figure 6 demonstrates this phenomenon. One filter comprises a 1.2m deep bed of the larger sand grains. The other comprises the smaller grains to a bed depth of 0.7m. Both filters were operated at 10 m/h with an inlet turbidity of 35 NTU and similar turbidity reduction is evident. This is considered to be due to the filter media providing an approximately equivalent surface area for floc attachment in both filter beds. The potential benefits from increasing bed depth viz. reduced headloss, must be balanced against an increased requirement for backwash water.

Conclusions

The CFF process utilising a natural polyelectrolyte as coagulant has been shown to be highly effective in the treatment of low turbidity raw waters at filtration rates less than 10m/h. The study is still continuing and as such no firm conclusions can be drawn. However, results do indicate that alterations in filter configuration, through changes in sand grain size and filter bed depth, can enhance performance depending on initial raw water conditions. Current work is examining the potential benefits of dual media beds in the CFF system. The use of a natural coagulant within such a treatment system is considered to offer significant advantages over proprietary chemical coagulants particularly for developing countries.

Acknowledgements

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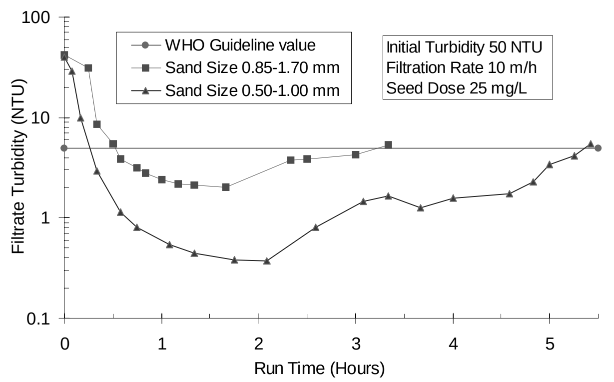

Figure 1 Effect of sand grain size on turbidity removal

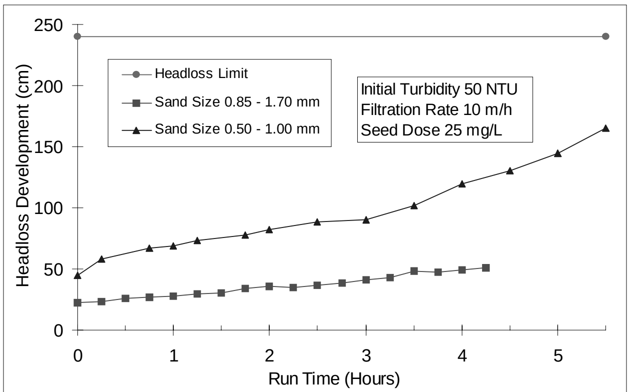

Figure 2 Effect of sand grain size on headloss development

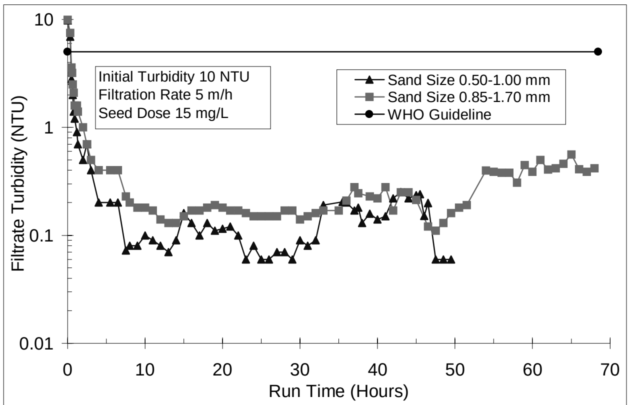

Figure 3 Effect of sand grain size on turbidity removal

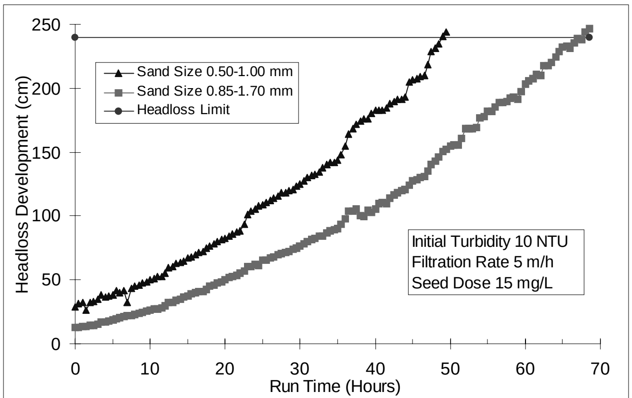

Figure 4 Effect of sand grain size on headloss development

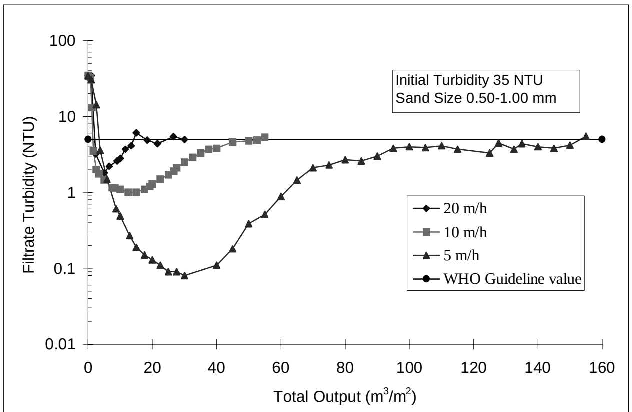

Figure 5 Effect of filtration rate on turbidity removal

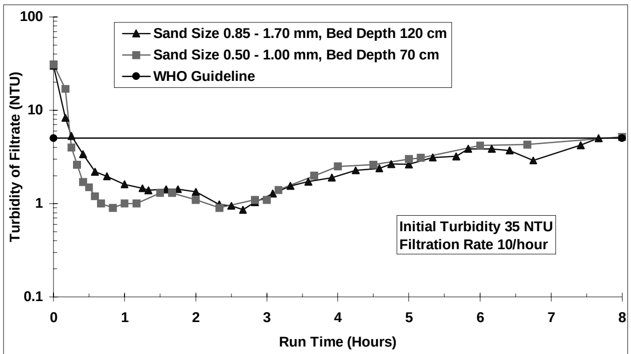

Figure 6 Effect of grain size and bed depth on turbidity