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WATER AND SANITATION FOR ALL: PARTNERSHIPS AND INNOVATIONS

Potentials of roughing filtration in Zambia

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AT PRESENT, THE Water and Sanitation Sector in Zambia is undergoing major reforms. As part of these reforms, it is envisaged that urban water supply systems, currently operated and maintained by (local) government institutions, are transformed into commercial utilities functioning independently and on an economic viable basis. For these utilities to function under these conditions, rehabilitation of many existing surface water treatment schemes is needed. In addition, the technologies used in these water treatment schemes need to be reviewed.

Slow sand filtration has been recognised as an excellent alternative for water treatment which often is economically competitive and has only limited requirements for operation and maintenance and is able to produce an effluent of low turbidity, free from offensive dissolved impurities and virtually free from harmful entero-bacteria, entero-viruses and protozoan cysts. As a result, SSF is widely applied in water treatment schemes in Europe, the USA and many developing countries. However, one of its main disadvantages is its limitation to treat surface water having high suspended solids loads and high levels of microbiological contamination (Galvis et al., 1993).

Pre-treatment appears to be the technical link missing for the application of SSF to small community water supplies, especially in developing countries (Collins et al., 1994). Given the simplicity of the SSF technology and the low costs involved in their operation and maintenance, it is important for pre-treatment systems to be used together with slow sand filtration, to portray similar features.

Roughing filtration is increasingly becoming accepted as a viable and efficient natural pre-treatment alternative in both developed and developing countries (Collins, et al., 1994, Galvis, et al., 1993 and Wegelin, 1996). The performance of roughing filters is based on a combination of transport, attachment and purification mechanisms, including screening, sedimentation, absorption, biochemical oxidation and bacteriological activity (Galvis et al., 1993).

Various types of roughing filters have been developed: horizontal-flow (HRF), downflow (DRF) and upflow roughing filters in series (URFS) and in layers (URFL). The main selection criteria for roughing filtration are based upon raw water quality characteristics: turbidity, suspended solids, colour, iron, manganese and faecal coliform levels (Galvis et al., 1993 and Wegelin, 1996).

The following removal efficiencies for full-scale upflow roughing filters in layers (URFL), operating with filtration rates ranging from 0.30 to 0.75 m/h have been reported (Galvis et al., 1993): 69 - 83 per cent for turbidity; 92 - 97 per cent for suspended solids; 29 - 68 per cent for true colour; >65 per cent for both iron and manganese; 97.7 - 99.7 per cent for faecal coliforms; and >50 per cent for COD.

In Zambia, slow sand filtration is incorporated in 21 surface water treatment schemes, of which 18 are preceded by conventional pre-treatment while 3 systems have no pre-treatment at all. Technical shortcomings, as well as inadequate operation and maintenance practices, have resulted in short filter runs (especially during the rainy season) and the production of drinking water of a poor and unreliable quality (Holzhaus, 1993).

Recently the University of Zambia, Lusaka, Zambia, in collaboration with Delft University of Technology, Delft, The Netherlands have embarked on a research programme on surface water treatment. This programme seeks to enhance local research capacity and, thus, contribute towards improved water supply practices in Zambia.

This paper presents some preliminary results of a pilot plant research on slow sand filtration and upflow roughing filtration in layers. The research envisages to assess the potential of roughing filtration in Zambia; more specifically its potential to provide a cost-effective and reliable pre-treatment step for slow sand filtration; and identify the modalities under which it can be incorporated into the existing full-scale water treatment systems.

Methods and materials

The pilot plant comprises two identical treatment lines each having one upflow roughing filter in layers (URFL) and one inlet controlled slow sand filter (SSF) (Table 1 and Figure 1). The filter media for both URFL and SSF were obtained from natural local sources. Raw water was drawn from the Kafue River, one of the major rivers in Zambia. The river normally exhibits low turbidity levels during the dry season (daily averages of 3-30 NTU), with peaks of 50-300 NTU occurring during the rainy season. Since the pilot plant was operational during the dry season, clay suspension were prepared using clay from the Kafue river banks to simulate turbidity peaks.

The URFL was operated at average filtration rates of 0.4, 0.5, 0.75m/h, while the SSF was operated at an average rate of 0.2m/h. The raw and filtered waters were checked for turbidity, total suspended solids and coliform organisms. Filter resistance was also monitored by means of piezometer tubes installed at various heights of the filter beds.

Figure 1. Schematic layout of the URFL-SSF pilot plant

Figure 2. Average daily turbidity reduction by URFL ($V_{f(average)}$ = 0.4m/h)

Figure 3: Average daily turbidity reduction by URFL($v_{f(average)}$ = 0.75m/h)

Table 1. Description of the pilot plant filter units

Results and discussion

During the first trial (from March 2nd until March 31st, 1997) the URFL was operated at a filtration rate of 0.4m/h. During this period, average turbidity removal ranged from 32-93 per cent, with average daily influent turbidities between 1.08-10.67 NTU (Figure 2). The URFL effluent remained below 2 NTU in nearly all cases.

During the second trial (from April 2nd until April 15th, 1997) the URFL was operated at a filtration rate of 0.75m/h. During this period, average turbidity removal ranged from 45-80 per cent, with average daily influent turbidities between 2.10-5.11 NTU (Figure 3). Again, URFL effluent remained below 2 NTU in nearly all cases.

The range of turbidity removal efficiencies found during the first two trial is slightly broader than the one cited in literature (Galvis et al., 1993), probably due to the low influent turbidity levels. There is no significant difference in turbidity removal efficiencies between filters being operated at 0.4 and 0.75m/h. Again, this is most likely due to the low influent turbidities.

During the third trial (from April 16th until May 2nd, 1997) simulated raw water was fed to the pilot plant. For influent turbidity levels between 10 and 50 NTU the effluent turbidity was consistently below 5 NTU, while

Figure 4: Average daily turbidity reduction by URFL($v_{f(average)}$ = 0.5m/h)

influent turbidity levels between 50 and 300 NTU were reduced to levels below 10 NTU (Figure 4). These data indicate the capability of roughing filters to provide an effective barrier for slow sand filters against high turbidity peaks.

The roughing filters also proved effective in he reduction of suspended solids loads, reaching removal efficiencies between 95 and 99 per cent (Figure 5). These data underline the important role sedimentation plays in roughing filtration.

Bacteriological analysis revealed an average reduction of only 75 per cent reduction by URFL for raw water having total and faecal coliforms ranging from 70-300 and 50-200 per 100 ml respectively. This is attributed to the fact that the filters had only functioned for a relative short period (1-2 months) and, thus, haven't 'ripened'.

No significant headloss development (<5mm) was detected throughout all trials, due to the relatively low influent turbidity levels applied during the period.

The SSF produced an acceptable effluent with consistently low turbidity levels (<1 NTU) and low total and faecal coliform numbers (#1/100ml).

Conclusions

The preliminary results obtained during the first three trials, clearly indicate the potentials of upflow roughing filters in layers (URFL) as an adequate pre-treatment option. The turbidity and totals suspended solids removal efficiencied detected coincide with those cited in literature. In some case high turbidity removal (up to 98 per cent) were found.

During subsequent trials removal efficiencies for other water quality parameters (such as colour, iron and manganese) will be included. Filter cleaning procedures and its respective efficiencies, as well as filter performance during prolonged periods of high turbidity will also be addressed.

Furthermore, it is envisaged to start pilot plant research on 'direct upflow roughing filtration in layers' during the next phase of the research programme.

References

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Figure 5: Total suspended reduction by URFL($v_{f(average)}$ = 0.75m/h)

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