A performance evaluation and modification of the UNICEF upward-flow water filter

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The low-cost UNICEF household filter combined with a downflow polishing sand filter can substantially improve the quality of tropical surface waters.

PROVIDING SAFE drinking-water to the rural population of the South has been a challenging task. The consumption of unsafe water is known to be responsible for a large proportion of the disease burden in these regions.[1,2,3] The International Drinking Water Supply and Sanitation Decade was launched by the United Nations in December, 1980, 'to provide all people with water of safe quality and basic sanitary facilities by 1990', though according to an estimate by the World Bank rural water supply coverage probably did not exceed 45 per cent by 1990.[4]

It has become apparent that traditional water purification devices could provide a major solution to the problem of safe drinking-water in rural areas. A number of household water purification devices are on the market, but they are too expensive for the target population. A low-cost sand-charcoal-sand upward-flow water filter (the UNICEF filter),[5] is being promoted by the Technology Support Section of the UNICEF Eastern Africa Regional Office for household use in rural areas; a study was carried out to evaluate the performance of the UNICEF filter, using a laboratory test filter of similar specifications, and possible modifications were suggested.

The UNICEF filter

The UNICEF filter (Figure 1) consists of two cement tanks, a 40-litre untreated (raw) water storage tank placed on top of a 175 to 200-litre filter tank. The filter tank contains a 25 to 30cm-deep layer of crushed charcoal (about 5mm grain size), which is sandwiched between two 20 to 25cm-deep layers of fine sand, and is separated from the sand layers by thin cloth screens or sheets of fine gauze. Stones are placed around the inlet to prevent blockage, and a 5cm layer of gravel is packed above the stone layer. The raw water from the storage tank enters the filter tank at its base through a 1.25cm-diameter hose and pushes upwards through the filter bed. The clean filtered water (effluent) accumulates above the filter bed and is collected through an outlet hose.

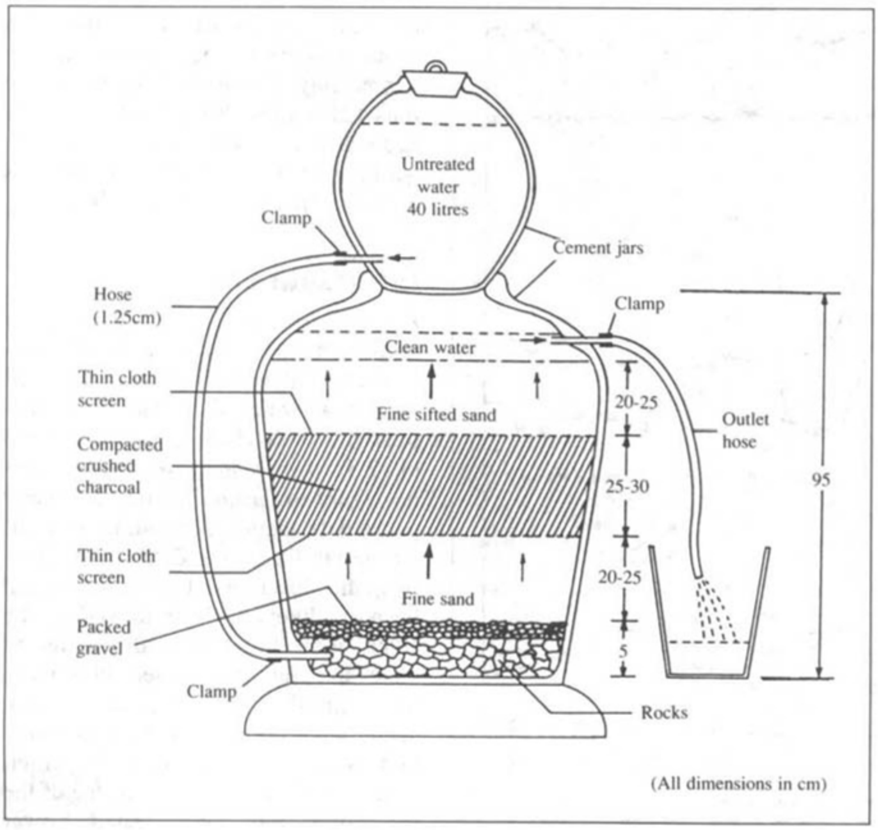

Figure 1. The UNICEF upward-flow water filter.

To establish the filtering action of the filter bed, the same water is passed through the filter some ten to twenty times, until the outlet water begins to clear. The raw water hose is then disconnected from the filter tank for a short time to allow the worst of the sediment to flow back out at the bottom. When this water no longer looks dirty, the hose is reconnected. The top 5 to 10cm of the fine sifted sand layer is removed and replaced with clean sifted sand, and water is passed through the filter several times to re-establish the filtering action. The filter is then ready for use. To maintain the filter, the top surface layer of sifted sand must be checked regularly, and cleaned if necessary. (When sediment is visible, the top 5 to 10cm must be removed and replaced with clean sifted sand.) When changing the top layer of sand no longer re-establishes good filtration, all the layers must be removed and replaced.

The filter is inexpensive to build, simple to use, and will provide enough water for a family or a group of about ten people. Depending on the quality of the raw water, it will operate for up to one year before it needs to be cleaned.

Experiments

The laboratory test filter consisted of a 100cm-long and 5cm-diameter perspex tube with a rubber stopper at the base. A 5mm hole was made in the centre of the stopper, so that raw water from the 10-litre storage bottle placed 95cm above the base of the test filter could flow in. The filter bed was placed above a 5cm layer of gravel (2cm mean size) and set up like a UNICEF filter: a 25cm layer of sand at the bottom (0.3-1.3mm grain size), a 25cm layer of crushed charcoal above it (5.0mm grain size), and a 25cm layer of sifted sand on top (0.71mm grain size).

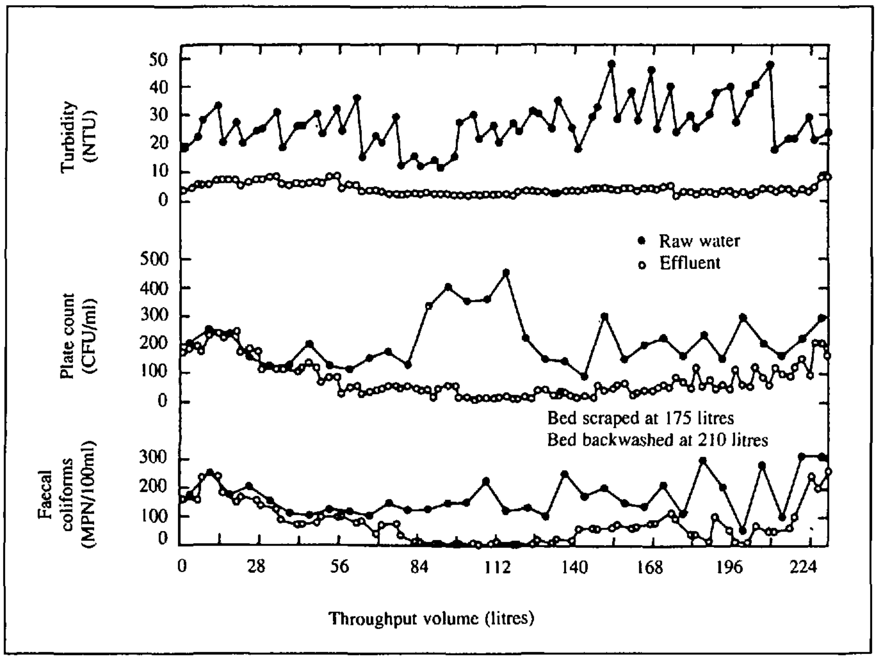

Figure 2. Performance of the test filter.

Water from the Lower Ganga Canal was used as the raw water; it had a pH of 7.9 to 8.5, a turbidity of 12 to 48 NTU, a heterotrophic plate count of 100-500 CFU/ml, and faecal coliforms of 50-320 MPN/100ml.

Seven litres of water were filtered in each run to mimic the normal pattern of use of a household water filter. The water was allowed to pass upward through the filter without any rate control, and it usually took three to four hours for the water to be filtered. The filtered water (effluent) was collected through a port 90cm above the base of the filter.

Before initiating the first filter run, seven litres of raw water were passed through the filter ten times, after which the effluent became clear. The top 5cm of the upper sand layer was removed and replaced with sand of the same size and water was passed through the filter several times to re-establish the filtering action. One filter run was usually made each day, and the filter bed was kept submerged between successive runs. Raw water and effluent samples were analysed for turbidity, heterotrophic plate count, and faecal coliforms.

Figure 2 shows the performance of the test filter in terms of raw water and effluent characteristics for thirty-three filter runs (231 litres throughput). Raw water and effluent samples corresponding to 1.0, 3.5, and 6.0 litres were collected in each run. Raw water samples at 3.5 litres were analysed for heterotrophic plate count and faecal coliforms, and those at 1.0 and 6.0 for turbidity. Effluent samples at 1.0, 3.5, and 6.0 litres were analysed for heterotrophic plate counts and turbidity, and those at 1.0 and 6.0 litres for faecal coliforms. The first nine runs (63 litres throughput) were somewhat erratic in terms of turbidity and plate count, after which both stabilized. Faecal coliforms in the effluent stabilized (microbiological maturation) after twelve runs (84 litres throughput). The best effluent characteristics (turbidity 1.5-3.0 NTU, heterotrophic plate count 10-50 CFU/ml, and faecal coliforms 10-20 MPN/100ml) were observed between the twelfth and eighteenth runs (84 to 126 litres throughput) after which the effluent quality gradually deteriorated.

After twenty-five filter runs (175 litres throughput), the top 5cm of the sand layer was scraped off and replaced with clean sand of the same size. Seven litres of raw water were passed through the filter bed five times to re-establish the filtering action. The effluent characteristics did not improve appreciably, however, and after five runs (210 litres throughput) the filter bed was backwashed. Following backwashing, filter performance was as erratic as that of a new filter bed.

Pre-treatment

As a first step to improve filter performance through operational modification, the test filter was operated with raw water that had been pretreated with doses of alum in the range of 2.5 to 6.9 mg/litre, which was necessary to destabilize the raw water particulate matter. According to particle destabilization and filtration theories, the destabilized particles would be more likely to be removed in the filter. In all filter runs with pre-treated water the water was dosed with alum, hand-stirred for two to three minutes, settled for 15 minutes, and the supernatant was passed through the filter. Figure 3 shows the performance of the test filter with alum-treated Lower Ganga Canal water: seven runs (49

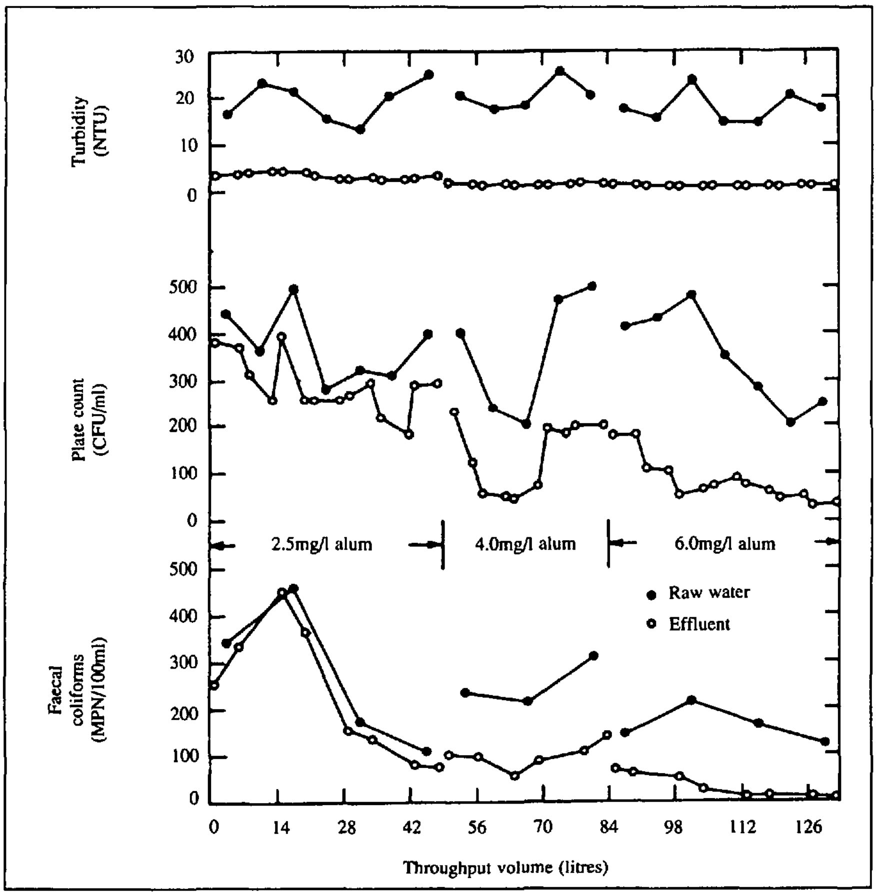

Figure 3. Performance of test filter with alum-treated Lower Ganga Canal water.

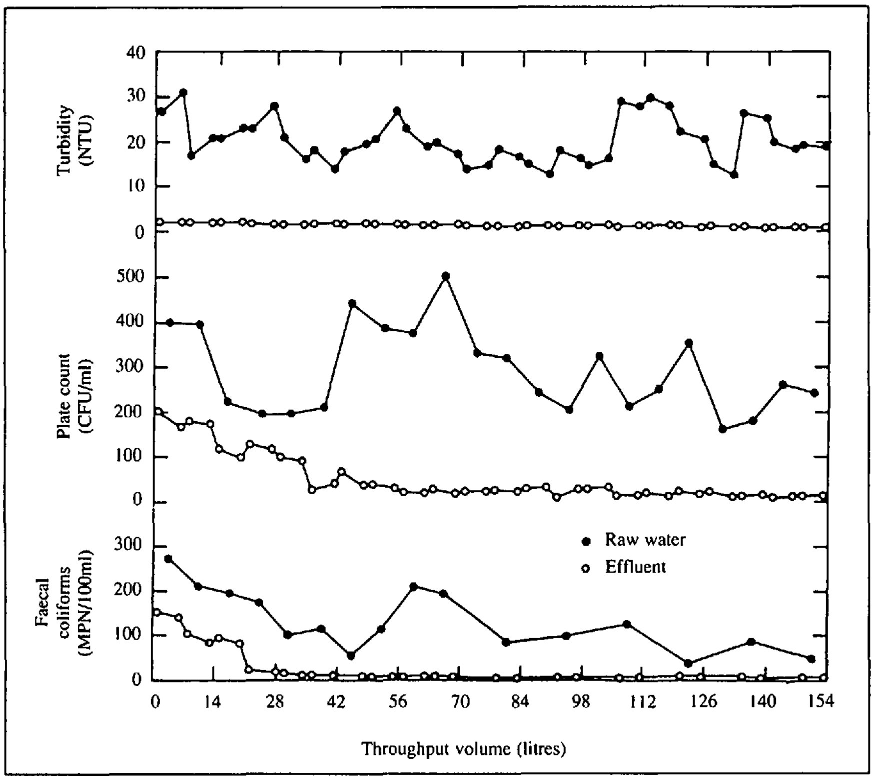

Figure 4. Performance of test filter with downflow polishing sand filter.

litres throughput) with 2.5mg/litre alum followed by five runs (49 to 84 litres throughput) with 4.0mg/litre alum. Even though pretreatment with 6.0mg/litre alum showed improvement in effluent turbidity as well as heterotrophic plate count and faecal coliforms, the effluent characteristics in terms of heterotrophic plate count and faecal coliforms were not noticeably superior to those without alum pretreatment (Figure 2), and hence the operational modification was not considered beneficial.

Based on observations[6] that up to 50 per cent of bacteria and other micro-organisms of faecal origin in tropical waters can be removed by upflow filtration using lower filtration rates and fine media, and that even if upflow filtration alone cannot adequately clarify water it might substantially relieve the load on slow sand and other filters, the test filter was operated with a downflow polishing sand filter as the second step to improve filter performance through operational modification. A 60cm deep sand bed (0.15-0.45mm grain size), similar to a slow sand filter, was used as the polishing sand filter. The effluent from the test filter was allowed to flow directly into the polishing sand filter and the final effluent was collected for analysis. According to the effluent characteristics of twenty-two filter runs (154 litres throughput) presented in Figure 4, performance of the test filter with the downflow polishing sand filter was commendable: turbidity of 0.5-1.5 NTU, heterotrophic plate count of 10-40 CFU/mL, and faecal coliforms below 10 MPN/100mL. This operational modification appeared to be a feasible way to improve the performance of the UNICEF filter.

The UNICEF sand-charcoal-sand upward-flow water filter, with an added downflow polishing sand filter of slow sand filter specification, is able to improve substantially the quality of tropical surface water, and appears suitable for use as a household water treatment device in rural areas of the South. As an alternative or addition to the polishing sand filter, boiling or chlorination with tablets could be considered. The filter should still be tested in terms of its efficiency in removing enteric viruses and protozoan cysts. ●

References

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