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WATER, SANITATION AND HYGIENE: CHALLENGES OF THE MILLENNIUM

Foam protected slow sand filters

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Slow sand filters (SSF) have been used to deliver potable water to the public since the early nineteenth century. The first recognised use of slow sand filtration for water supply was in Paisley, Scotland in 1804 when John Gibb set up an experimental slow sand filter to supply his bleachery (Baker, 1981). Being an enterprising fellow, he sold his surplus water to the public. By 1852 the health advantages of filtered water were so evident that the Metropolis Water Act required all river Thames water to be filtered before use by Londoners. The 1854 Broad Street cholera outbreak further reinforced the need to filter public water supply. Since then slow sand filters have been adopted by many major towns including London for potable water treatment and are still in use today. Slow sand filters have largely been superseded by rapid sand filtration in western countries where the 100 fold increase in production per unit surface area is an advantage. Slow sand filters provide an appropriate low cost water treatment option for low and middle income communities where land requirements are not an issue. Slow sand filters have few moving parts. They require no chemical pre-treatment and can cope with raw water turbidities up to 20 NTU before roughing filtration or sedimentation is necessary. They have been found to effectively capture and destroy bacteria, oocysts and viruses. The major cost associated with slow sand filter operation is the need for periodic removal of the top 20 or 30 mm of sand to recover loss of head. This is a time consuming and manually intensive operation. Slow sand filter cleaning can be necessary after only a few weeks for poor raw water conditions. Methods for extending filter run time before cleaning is required have been investigated. Filter fabrics have been shown to extend filter operation by many factors before terminal head loss is reached (Luxton and Graham, 1998). This paper reports a laboratory study of polyurethane (PE) foam as a method of extending filter run time. A previous study showed that a thick layer of foam extended slow sand filter operation time by several factors (Vochten *et al*, 1988). One possible advantage of PE foam is the potential for cleaning and reuse of the foam many times before replacement is necessary. PE foam can easily be cleaned by squeezing by hand in running water. The elasticity of the PE foam causes it to return to its original shape after being cleaned.

Materials and Methods

An experimental slow sand filter was constructed in the laboratory. The slow sand filter and associated equipment are shown in Figure 1. A stirred storage tank supplied the raw water to the filter column by peristaltic pump. The raw water was created from tap water dosed with kaolin and glucose and glutamic acid. The kaolin was added to create a low turbidity raw water of 2 to 5 nephelometric turbidity units (NTU). The glucose and glutamic acid were added to provide low concentrations of organic matter similar to a lowland river water. The filter comprised a perspex column 55 mm in internal diameter. The column was filled with 250 mm of filter sand. The sand had an effective size of 0.25 mm and a uniformity coefficient of 2.5. The aspect ratio of the column diameter to sand diameter was greater than 200, minimising the wall effects (Lang *et al.,* 1993). Two thin layers of PE foam (Declon, Corby, UK) were placed on top of the sand. The upper layer comprised 10 mm thick PE foam with a pore density of 30 pores per inch (ppi). The lower layer comprised 10 mm thick PE foam with a pore density of 45 ppi. The filter was operated at a surface loading of 0.15 metres per hour. The filter was operated on the principle of constant rate rising head. At the beginning of each test the filter was seeded with small amounts of *schmutzdecke* taken from a local slow sand filter water works. The surface of the filter was illuminated by a light source to stimulate biological growth. The light source was controlled by a timer set to provide 8 hours illumination per day to simulate outdoor conditions. Samples of raw water and filtered water were collected

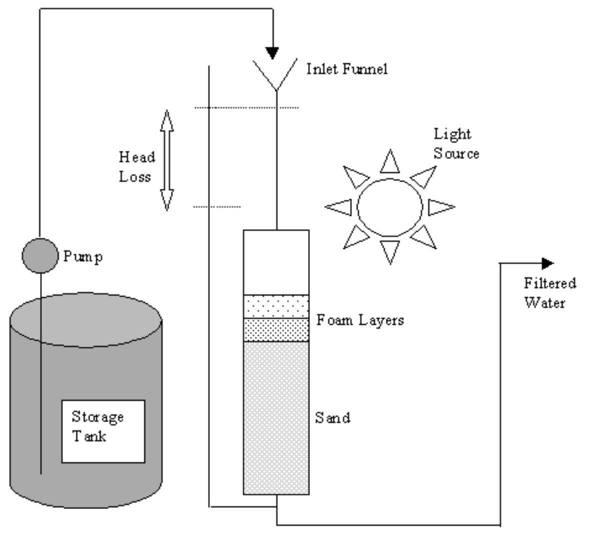

Figure 1: Slow sand filter apparatus

periodically for turbidity measurement. Turbidity was measured using a Hach ratio turbidimeter (model XR). The turbidimeter was calibrated following the manufacturer's instructions. Filter head loss was measured periodically using water piezometers connected above and below the filter media. The filter was operated repeatedly with and without the foam layers and the results compared.

Results and Discussion

Effect of foam on SSF head loss

The effect of the foam layers on the development of head loss is shown in Figure 2.

Control runs 1 and 2 were conducted with no foam on top of the filter sand. It can be seen that the filter developed some 500 to 800 mm of head loss over 30 to 50 days operation. Foam runs 1 and 2 were conducted with the layers of foam placed on top of the filter sand. It can be seen that the filter developed less than 60 mm of head loss during these tests. Observations of the development of the *schmutzdecke* were made during these experiments. Without the foam, the *schmutzdecke* was observed to grow on the surface of the filter sand blocking the surface pores. With the foam fitted, the schmutzdecke was observed to grow within the foam layers creating what is know as an *extended schmutzdecke* (Vochten *et al.*, 1988). The growth of the *schmutzdecke* within the foam and not directly on the surface of the filter sand significantly reduced the development of head loss. This technique would appear to extend the filter run time by many factors before terminal head loss will be reached. A previous study showed that a 100 mm thick layer of 80 ppi pore density PE foam could extend filter operation time by several factors (Vochten *et al.*, 1988). A similar extension in filter operation time has been achieved in this study using 2 thin layers of lower pore density foam (30 & 45 ppi) each only 10 mm thick. The foam has a high specific surface area and high porosity (~90%) compared to the underlying sand, providing sites for biological growth without significant head loss build-up.

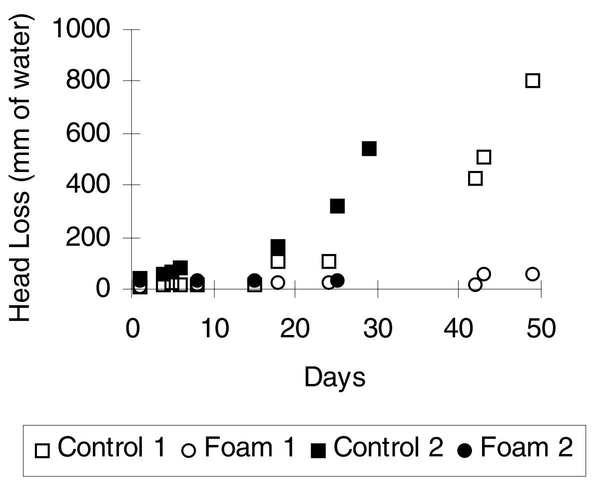

Figure 2. Effect of foam on SSF head loss.

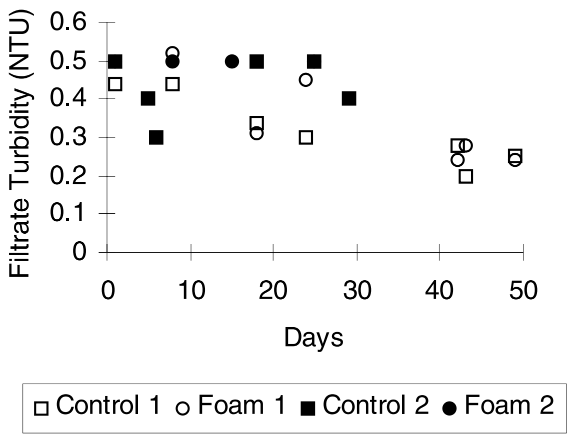

Figure 3. Effect of foam on filtrate turbidity.

Effect of foam on SSF filtrate turbidity

The effect of the foam layers on the filtered water turbidity is shown in figure 3. In Control runs 1 and 2, conducted over 50 and 30 days respectively, the average filtered water turbidities were 0.32 and 0.46 NTU. In Foam runs 1 and 2, conducted over 50 and 25 days respectively, the average filtered water turbidities were 0.34 and 0.5 NTU. The presence of the foam layers appeared to produce a marginally poorer filtered water quality but the difference of 0.02 to 0.04 NTU was not considered significant.

Cleaning and reusing the foam

After each test, the foam layers were removed from the filter column for cleaning. The foam layers were cleaned by squeezing the foam under running water. This simple procedure removed the bulk of the biological growth and the shape of the foam was recovered by the natural elasticity of the material. When the foam was used to protect the sand, little growth occurred on the surface of the sand itself. It was not necessary to scrape off the surface layer of sand, eliminating the need for deeper sand depths and resanding. Microscope inspection of the foam after reuse several times did not reveal any damage to the structural integrity of the foam suggesting a significant lifetime. Microscope inspection of the removed biomass found single cell algae, attached and free swimming protozoa and nematodes indicating an established ecology. The use of PE foam to extend filter operation time would appear to have advantages over materials which are discarded after one or two cycles. The use of thin layers of lower pore density PE foam can extend filter operation time similar to the thick layer of high pore density foam used in the previous study. In addition, the lower pore density foam in thin layers is easier to clean. Several questions remain unanswered. How does the foam perform under field conditions? Can it be effectively cleaned repeatedly without structural damage? Can filamentous growth be removed? Is the foam affected by photodegradation or biodegradation in the long term? Pilot plant studies are recommended to address these issues.

Conclusions and recommendations

- Slow sand filter operation time may be significantly extended by the use of PE foam on top of the filter sand.
- PE foam encouraged the growth of an *extended schmutzdecke* within the foam, reducing the build up of head loss.
- 20 mm of PE foam was sufficient to extend operation time by several factors.
- The presence of the PE foam did not significantly affect the turbidity of the filtered water.
- The PE foam can be easily cleaned by hand and reused repeatedly.
- Larger scale pilot plant studies are necessary to determine the performance of foam protected slow sand filters under field operating conditions.
- Filtrate bacterial quality should be studied to ensure the foam has no detrimental effect on slow sand filter micro-organism removal.
- Analysis of the cost/benefit of PE foam is needed to justify its use. Lifetime estimates from pilot plant studies are needed for this analysis. The cost of the foam should be compared with the savings in labour and materials.

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References

BAKER, M. N., *The quest for pure water: the history of water purification from the earliest records to the twentieth century.* American Water Works Association, 2nd Ed., Vol. 1, 1981, USA.

LANG, J. S., GIRON, J. J., HANSEN, A. T., TRUSSELL, R. R. and HODGES, W. E., *Investigating filter performance as a function of the ratio of filter size to media size.* Journal American Water Works Association, Vol. 85, 1993, pp. 122-130.

LUXTON, P. and GRAHAM, N., *Natural fabrics in slow sand filtration.* Proceedings 22nd WEDC Conference, New Delhi, India, 1996, pp. 275-278.

VOCHTEN, P., LIESSENS, J. and VERSTRAETE, W., *The application of polyurethane to improve slow sand filters.* In: *Slow Sand Filtration*, Ed. GRAHAM, N. J. D., Ellis Horwood, 1988.