Home water treatment by direct filtration with natural coagulant

Raveendra Babu and Malay Chaudhuri

ABSTRACT

Seeds of the plant species *Strychnos potatorum* and *Moringa oleifera* contain natural polyelectrolytes which can be used as coagulants to clarify turbid waters. In laboratory tests, direct filtration of a turbid surface water (turbidity 15–25 NTU, heterotrophic bacteria 280–500 cfu ml^{-1}, and fecal coliforms 280–500 MPN 100 ml^{-1}), with seeds of *S. potatorum* or *M. oleifera* as coagulant, produced a substantial improvement in its aesthetic and microbiological quality (turbidity 0.3–1.5 NTU, heterotrophic bacteria 5–20 cfu ml^{-1}, and fecal coliforms 5–10 MPN 100 ml^{-1}). The method appears suitable for home water treatment in rural areas of developing countries. These natural coagulants produce a 'low risk' water; however, additional disinfection or boiling should be practised during localised outbreaks/epidemics of enteric infections.

Key words | direct filtration, fecal coliforms, heterotrophic bacteria, home water treatment, natural coagulant, poliovirus

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INTRODUCTION

Groundwater is the preferred source for drinking water in rural areas of developing countries and it generally requires no or minimal treatment. In the event that no suitable aquifers are available, relatively clean waters from lakes or streams are preferred. However, only simple, practical technologies such as gravity chemical feed with solutions, hydraulic rapid mixing and flocculation, horizontal-flow sedimentation, and manually operated filters should be used for treatment of such waters (Schulz & Okun 1984).

Natural polyelectrolytes of plant origin have been used for many centuries in developing countries for clarifying turbid water (Schulz & Okun 1984). For home water treatment, the materials have to be used in the form of powder or paste, 90% of which consists of substances other than the polyelectrolytes. Even under such conditions, a few plant seeds make effective coagulants (Jahn 1988): for example, seeds of the plant species of the family *Loganiaceae* – *Strychnos potatorum*, and *Moringaceae* – *Moringa oleifera* and *Moringa stenopetala*. *S. potatorum* is a small tree occurring abundantly in central and southern India. Among the different species of *Moringaceae*, *M. oleifera* is the most widely occurring tree. Although it is native to northern India, it has become pantropical because of its many uses. Reference to the use of *S. potatorum* seed for clarifying turbid water is available in *Sushruta Samhita* (Bhishagratna 1991), and it is still in use in the villages of Maharashtra and Tamil Nadu in India. The village women of Sudan use *M. oleifera* seed for home water treatment (Jahn 1981).

In laboratory and field studies, seeds of *S. potatorum* and *M. oleifera* have shown promise as coagulant in the clarification of turbid water (Sen & Bulusu 1962; Dhekane *et al.* 1970; Tripathi *et al.* 1976; Jahn 1988; Sutherland *et al.* 1990, 1994; Folkard *et al.* 1995; Al-Khalili *et al.* 1997; Ndabigengesere & Narasiah 1998; Folkard & Sutherland 2002). In laboratory tests, direct filtration with *S. potatorum* seed as coagulant appeared effective in clarifying a low turbidity water (Abu-Ghararah 1983). A method for home water treatment comprising coagulation by *M. oleifera* seed and filtration through a meshed sand filter or a sand-charcoal filter was suggested (Jahn 1981; Setyawaty 1989).

The present study used a coagulation-filtration test to examine quality improvement of a surface water by direct filtration with *S. potatorum* seed or *M. oleifera* seed as the coagulant. The goal was to assess suitability of the method for home water treatment in rural areas of developing countries.

PREPARATION OF COAGULANT

Dried *S. potatorum* seeds were powdered and sieved through a 150 μm sieve, and a 2% suspension was prepared with distilled water. Kernels of dried *M. oleifera* seeds were thoroughly pounded in a mortar to produce a somewhat pasty powder, and a 2% suspension was prepared with distilled water.

COAGULATION-FILTRATION TEST

Treatment of surface water by direct filtration with *S. potatorum* seed or *M. oleifera* seed as the coagulant was examined in a coagulation-filtration test. Characteristics of the raw water were pH 8.1–9.1, alkalinity 76–110 mg $CaCO_3\,l^{-1}$, turbidity 15–25 nephelometric turbidity units (NTU), heterotrophic bacteria 280–500 colony-forming units per ml (cfu ml^{-1}), and fecal coliforms 280–500 most probable number per 100 ml (MPN 100 ml^{-1}). A batch coagulation test – jar test with a filtration step (Hudson & Wagner 1981) – indicated that 1.0–2.0 mg l^{-1} of *S. potatorum* seed or 100–200 mg l^{-1} of *M. oleifera* seed dose was adequate for clarification of the water when initial turbidity was 18–21, 38–42 or 130–135 NTU. In the procedure, 10 l of the water was dosed with a coagulant (1.5 mg l^{-1} of *S. potatorum* seed or 200 mg l^{-1} of *M. oleifera* seed) and mixed by hand-stirring for 2–3 min, then passed through a laboratory sand filter (1,000 mm long and 50 mm ID glass column with 500 mm of river sand of geometric mean size 0.6 mm) from an overhead (2,000 mm above the filter outlet) reservoir, at an initially adjusted filtration rate of 10 m h^{-1}.

Two filter runs were conducted daily (morning and evening), and the filter was kept submerged in water in the intervening period. One sample of raw water and three samples of filtered water (1, 5 and 9 l throughput) were collected in the morning, and examined for turbidity, heterotrophic bacteria and fecal coliforms. In the evening, samples of raw and filtered water were examined for turbidity alone. A pour plate method (35 °C incubation for 48 h on plate count agar) was used for enumeration of heterotrophic bacteria, and a multiple-tube fermentation technique (35 °C incubation for 24 h on lauryl tryptose broth followed by 44.5 °C incubation for 24 h on EC broth) was used for fecal coliform enumeration (*Standard Methods*, 1995).

The quality of filtered water with *S. potatorum* seed as coagulant is shown in Figure 1. The first two filter runs produced water with slightly higher turbidity (2.0–2.5 NTU), presumably due to non-ripening of the filter. Consistent filtered water quality was observed from the 3rd to 24th filter run (20–240 l throughput): turbidity 0.3–1.5 NTU, heterotrophic bacteria 5–15 cfu ml^{-1} and fecal coliforms 5–10 MPN 100 ml^{-1}. Thereafter, quality of filtered water deteriorated and filtration rate declined. The filter was backwashed (50% bed expansion) after the 30th filter run (300 l throughput). Following backwashing, six more filter runs (60 l throughput) were conducted, and quality of filtered water was as before.

When *M. oleifera* seed was used as coagulant, the filter clogged within the first six filter runs (60 l throughput), presumably because of the higher dose (200 mg l^{-1}) of the coagulant. A batch coagulation test, conducted with the settled solids of *M. oleifera* seed suspension, showed meagre removal of turbidity, indicating that the soluble fraction of the suspension was effective as coagulant. In a subsequent coagulation-filtration test, raw water was dosed with the supernatant of a 30-min settled suspension of *M. oleifera* seed. The quality of the filtered water is shown in Figure 2. Consistent filtered water quality was observed from the 3rd to 13th filter run (20–130 l throughput): turbidity 0.3–1.1 NTU, heterotrophic bacteria 5–20 cfu ml^{-1} and fecal coliforms 5–10 MPN 100 ml^{-1}. Thereafter, quality of filtered water deteriorated and filtration rate declined. The filter was backwashed (50% bed expansion) after the 16th filter run (160 l throughput). Following backwashing, six more filter runs (60 l throughput) were conducted, and quality of filtered water was as before.

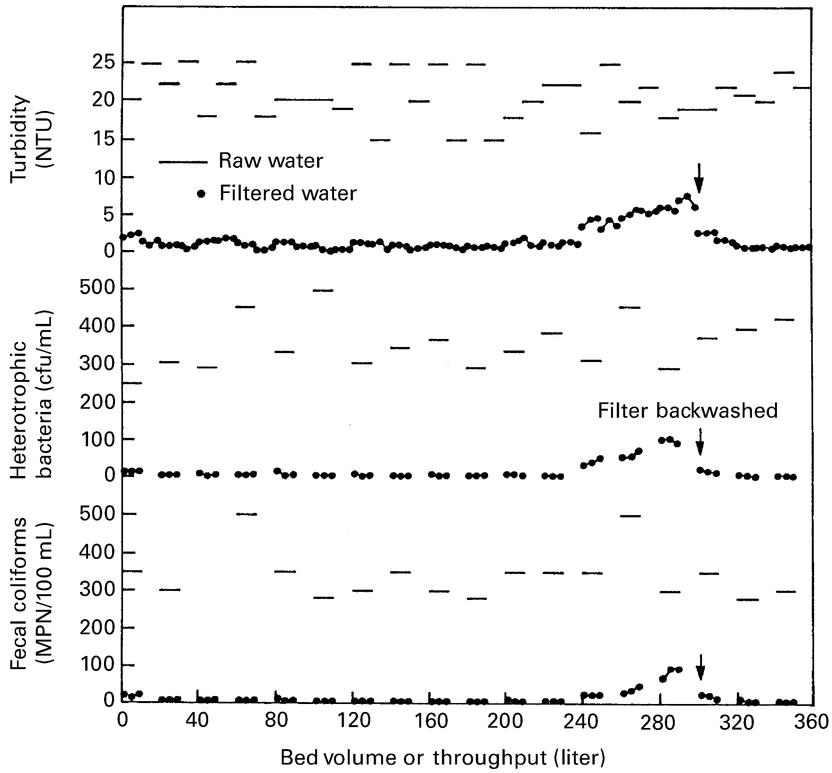

Figure 1 | Filtered water quality with *S. potatorum* seed as coagulant.

To examine reduction of viruses by direct filtration with *S. potatorum* seed or *M. oleifera* seed as coagulant, 5 l of raw water were spiked with poliovirus (grown on a MA-104 cell line and purified by centrifugation) to produce a challenge level of 2,370,000–5,000,000 plaque-forming units per litre ($PFU\,l^{-1}$), and used in the third filter run following backwashing of the filter. Two samples of filtered water (1.5 and 3.5 l throughput) were collected and examined for poliovirus, by plaque assay (Smith & Gerba 1982), on an MA-104 cell line. Virus reduction effected was 3 log by *S. potatorum* seed and 3–4 log by *M. oleifera* seed.

Results of the coagulation-filtration tests indicate that seeds of *S. potatorum* and *M. oleifera* contain materials that can serve as coagulant in direct filtration of water, and effect removal of turbidity, bacteria and viruses from water.

CONCLUSIONS AND COMMENTARY

Seeds of *S. potatorum* and *M. oleifera* contain materials that are effective as coagulant, and direct filtration of water with *S. potatorum* seed or *M. oleifera* seed as coagulant brings about a substantial improvement in its aesthetic and microbiological quality. The method appears suitable for home water treatment in rural areas of developing countries. It may not produce fecal coliform-free water, but definitely produces water with 'low risk' according to the microbiological water quality classification scheme of the World Health Organization, based on thermotolerant (fecal) coliforms (WHO 1997). It is to be noted that even if great attention is paid to selecting the purest available water source and distributing the water through a well-designed and maintained system, it will not be usually possible to meet a zero fecal coliform standard without chlorination (Feachem 1980). Additional disinfection or boiling should be practised during localised outbreaks/epidemics of enteric infections.

A simple arrangement for home water treatment would be to dose 10 l of raw water (pre-settled if initial turbidity is *c.* 100 NTU) with *S. potatorum* seed or *M. oleifera* seed as coagulant, mix by hand-stirring for 2–3 min, and filter the water directly through a 500-mm sand filter. The sand filter may be made of a

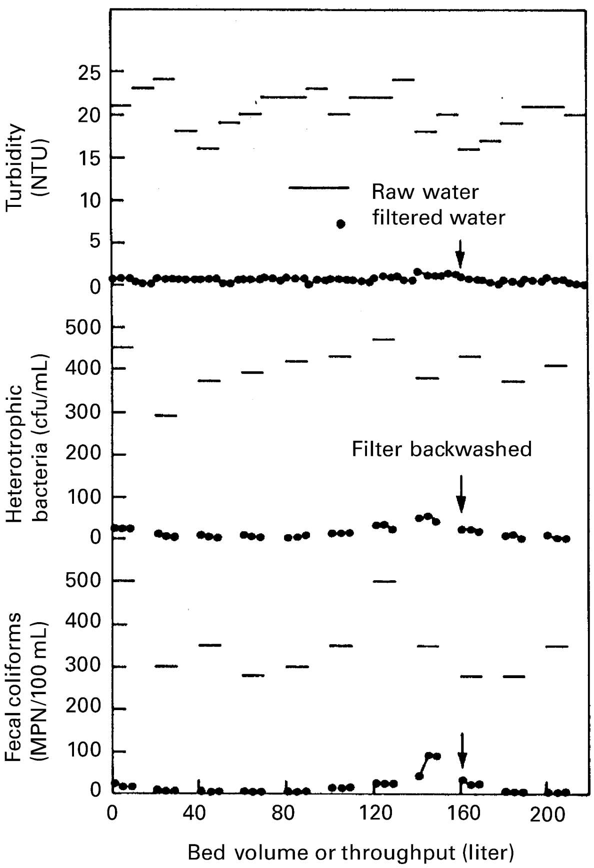

Figure 2 | Filtered water quality with *M. oleifera* seed as coagulant.

1,200 mm long and 150 mm ID PVC pipe, packed up to a depth of 500 mm with fine river sand, with 20–30 mm of pea-sized gravel at the bottom and arrangement for producing an initial flow rate of $3 l min^{-1}$. Two to three filter runs may be conducted daily. When a considerable reduction in filtration rate occurs, the sand should be removed from the filter, washed clean with water and put back in the filter.

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