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AFFORDABLE WATER SUPPLY AND SANITATION

Moringa oleifera as a natural coagulant

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CRUSHED SEEDS of the tree *Moringa oleifera* Lam. (*M.oleifera*) are a viable replacement coagulant for proprietary chemicals such as aluminium sulphate (alum) in developing countries. The tree is a multi-provider that grows pantropically and its uses, global distribution and some vernacular names are given.

Results of full scale treatment trials using *M.oleifera* as the sole coagulant are presented. The study was conducted in February 1994 at the Thyolo treatment works in southern Malawi under the auspices of the Ministry of Works Water Department. The works comprises flocculator-clarifiers, rapid gravity filters followed by chlorination. Imported alum and soda ash are the coagulants normally used on the works. When replaced by *M.oleifera* seed solution comparable treatment performance was achieved. This is the first time that any naturally derived material has been successfully used as a primary coagulant on such a scale (works flow 60 m^3 / hour) with the treated water entering supply. Inlet turbidities during the trials ranged between 270 and 380 NTU. Finished water turbidity was consistently below 4 NTU.

M.oleifera seeds yield a vegetable oil high in oleic acid and thus of high market value for cooking and soap manufacture. The presscake remaining after oil extraction contains the active components effecting coagulation. The economic case for adoption of this natural coagulant in Malawi is overwhelming and a brief summary is presented. The implications of this study are not specific to Malawi but directly relevant to many countries in Africa, Asia and South America.

Background

The Overseas Development Administration of the British Government is funding work by the Environmental Engineering Group at Leicester University relating to the use of natural coagulants for water treatment in developing countries. Collaborating agencies in Malawi include the Civil Engineering Department of the Polytechnic, Ministry of Works and Supplies Water Department and the Forestry Research Institute of Malawi.

River water drawn for human consumption and general household use can be highly turbid particularly in the rainy season. River silt is churned into suspension and run off from fields and other surfaces carries solid material, bacteria and other micro-organisms into the river. It is of paramount importance to remove as much of this suspended matter as possible prior to consumption. This can generally only be achieved by the addition of coagulants to the raw water within a controlled treatment sequence. In many developing countries proprietary chemical coagulants, such as alum and synthetic polyelectrolytes, are either not available or available at considerable cost. An alternative is the use of natural coagulants, generally of plant origin, to effect coagulation.

In certain areas of the developing world natural coagulants have been used for centuries within traditional water treatment practices. One of the main thrusts of work at Leicester has been to optimise scale up from this individual household level to continuous flow water treatment works. The work has focused on the coagulation properties of crushed seed material of the tree *Moringa oleifera* Lam. (*M.oleifera*). A native tree of northern India, this *Moringa* species is now widely cultivated throughout the tropics and is found in many countries of Africa, Asia and South America. The two most common English vernacular names for the tree are 'drumstick' (describing the shape of its pods) and 'horseradish' (describing the taste of its roots). *Moringa* grows rapidly from seed and cuttings even in marginal soils, demands little or no horticultural attention and possesses a hardiness that enables it to survive prolonged periods of drought. Although normally associated with tropical lowlands it has been reported to grow at elevations up to 1200m in protected mountain areas. This study has confirmed the prolific growth rates reported in the literature. At trial plantations

Table 1. Products and uses of the *M.oleifera* tree.

Seed	• crushed whole seed or presscake remaining after oil extraction as a coagulant for water and wastewater treatment
Vegetable	• green pods as fresh or canned vegetable • leaves and flowers used as a relish
Oil	• seeds contain 40% oil by weight • used for cooking, soap manufacture, as a cosmetics base and to provide illumination
Other uses	• all plant organs as constituents in traditional medicines • leaves and oil presscake as cattle fodder • grown as live fences and wind breaks • wood from coppicing as a fuel source

established near Nsanje in southern Malawi, seedlings achieved 4 metres in height within 12 months of planting out with flowers and fruit obtained within this first year. After 2 years the trees matured to 6 metre tall specimens. In some areas of southern India two harvests of seed pods are possible in a single year. *M.oleifera* is often described as a 'multi-provider' and table 1 provides details.

For water treatment application, the seed pods are allowed to dry naturally on the tree prior to harvesting. The seeds are easily shelled, crushed and sieved using traditional techniques employed for the production of maize flour. Dosing solutions are generally prepared as 1-3% solutions (the full scale trial reported was dosed with a 4% seed solution due to the limited capacity of the dosing pump available). The crushed seed powder, when mixed with water, yields water soluble proteins that posses a net positive charge. The solution acts as a natural cationic polyelectrolyte during treatment (Sutherland,J.P., Folkard,G.K. and Grant,W.D., 1990).

Water treatment at full scale

It is now regarded as axiomatic that both water and wastewater technology for developing countries must be no more complex than strictly necessary, be robust and cheap to install and maintain. A prototype treatment works was designed at pilot scale based on this philosophy. The pilot plant was constructed within the grounds of the Thyolo Water Treatment Works, the works being controlled by the Ministry of Works and Supplies Water Department. The pilot plant was successfully commissioned during the 1992 rainy season. The source river exhibited turbidity levels in excess of 400 NTU throughout the study period. Solids removal within the plant was consistently above 90% following a gravel bed flocculation stage and plain horizontal flow sedimentation. Subsequent rapid gravity sand filtration gave a final, treated water turbidity generally well below 5 NTU. *M.oleifera* seed dose ranged from 75 - 250mg/l depending on the initial raw water turbidity (Folkard,G.K., Sutherland,J.P. and Grant,W.D., 1993).

Following on from the success at pilot scale, permission for full scale trials was received from the Malawian authorities. The main works at Thyolo consist of upflow contact clarifiers followed by rapid gravity filters. The clarifiers are in a state of disrepair with the impeller drives and chemical feed pumps not functional. Soda ash and alum solutions are introduced into the incoming flow via simple gravity feed systems. These chemicals are imported from South Africa at an annual cost equivalent to £26,000 (1993 estimates of costs solely for Thyolo works) of foreign exchange expenditure. Trials are currently underway at Thyolo evaluating a synthetic polyelectrolyte as a potential replacement.

M.oleifera seed for the full scale trials was purchased from villagers in the Nsanje region. The tree is cultivated extensively in this region, being highly prized primarily as a provider of a fresh green vegetable.

The results of 2 typical trials are given as figures 1 and 2. The works were operated at 60 m^3/hr with the coagulant solutions dosed and monitored using a small centrifugal pump and rotameter respectively. Figure 1 shows the results of dosing *M.oleifera* seed solution at 75mg/l over a seven hour period. This treatment performance compares favourably with that given in figure 2 with alum dose at 50mg/l. Turbidity removal rates within the clarifiers are approximately 80% over both trials. An improved filtrate turbidity for the subsequent alum treatment is due to the sand filters having experienced a longer run in time.

Economic analysis

Moringa seed contains 40% by weight of oil and laboratory work at Leicester confirmed that the presscake remaining after oil extraction still contains the active coagulant. The high quality and hence high market value of this vegetable oil was confirmed during the recent visit to Malawi. The oil is of equal value as a cooking oil and as the principal ingredient for soap manufacture. The demand for oil in Malawi far outstrips the available raw materials required for extraction. Crude Soya bean oil is imported from South America to make up the shortfall. Blended vegetable oil retails in local stores at a cost equivalent to three times that of the current U.K.price. An economic analysis in the Malawi context reveals that the presscake may be obtained at zero net cost as a by-product of oil extraction. The results of this analysis are summarised in Table 2.

Conclusions

The pilot and full scale trials in Malawi have demonstrated the effectiveness of *M.oleifera* seed coagulant for the clarification of highly turbid river water. Inlet turbidities of 270-380NTU were consistently reduced to below 4 NTU in the finished water.

Table 2. Cost comparison of alternative coagulants for Malawi.

Alum and soda ash (Ministry of Works, Thylo)	501
Floccotan polyelectrolyte (Lilongwe Water Board)	107
Anikem polyelectrolyte (Blantyre Water Board)	106
Moringa seed purchased from smallholder farmers	75
Moringa plantations operated by water utilities	0 (plus operating profit)

- Costs expressed as Malawi Kwacha (MK) per 1000m3 of water treated
- MK 10.07= £1 sterling (March 1993)

Figure 1. Main works operating at 60m³/hr with *M.olerifera* seed solution dosed at 75mg/l.

Figure 2. Main works operating at 60m³/hr with *alum* solution dosed at 50mg/l.

M.oleifera seed contains 40% by weight of oil, with the presscake remaining following oil extraction containing the active constituents effecting coagulation. Confirmation of the high market value of the oil make the economic case for adoption of the presscake as a coagulant overwhelming.

The growth of *M.oleifera* trees by smallholder farmers should be promoted. This crop diversification strategy will provide both vegetables and a raw material for oil extraction. Simple and proven technology is available to allow small scale oil milling enterprises to be established in the rural areas with many benefits accruing.

Future work

A further field study in Malawi is planned for August 1994. Contact flocculation filtration, with *M.oleifera* solution introduced to the raw water immediately prior to the filter, has proved very effective at low to moderate turbidities under laboratory conditions. This treatment will be investigated at pilot and full scale at the Thyolo site.

Management trials at the existing *M.oleifera* plantation at Makhanga in southern Malawi are planned. The effects of alternative management options (coppicing, pollarding etc.) will be investigated with a view to optimising seed yield. Species / provenance trials are also proposed, incorporating varieties or cultivars of *M.oleifera* available from India and elsewhere.

The efficiency of oil extraction from *M.oleifera* seed will be determined using a range of small scale devices currently available (from motorised screw impellers to simple hand presses). The presscake residues from these batch tests will be evaluated as treatment coagulants.

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