Natural coagulants for appropriate water treatment: a novel approach

by J.P. Sutherland, G.K. Folkard and W.D. Grant

Recent field trials in Malawi have proved the viability of using indigenous *Moringa* seeds to clarify turbid waters.

IT HAS BEEN ESTIMATED that of the 1200 million people who are without safe drinking-water, some 80 per cent live in relatively small rural communities. In most situations villagers draw water for drinking from surface sources. For a riparian population in the rainy season, these sources are highly turbid and on occasions contain bacterial concentrations similar to that of weak raw sewage.

Against this background, small-scale and household water-treatment systems have an important role to play in providing aesthetically pleasing and bacteriologically safe drinking-water. Chemical treatment of surface waters, using for example aluminium sulphate (alum), is generally prohibitive because of the high cost, the lack of skilled workers needed for its application, and the uncertainty of the quantity and quality of supplies. The use of slow sand filters as an alternative has met with some success, but there are the problems of the initial cost and the continuous maintenance. Furthermore pre-settlement is necessary for higher turbidities.

In an attempt to find a cheap and simple method of treating surface waters, attention has been focused on the use of natural substances as primary coagulants for the removal of suspended organic and inorganic matter. The clarifying powers of natural substances are well known in many remote areas of the developing countries and, indeed, their use has been traced back 4,000 years. Seed suspensions of *Moringa Oleifera* and *M. Stenopetala* have been used for many centuries in the Sudan and this traditional usage has been promoted over recent years in areas of Indonesia, South America and North East Africa. As an alternative to chemical treatment their use has many advantages including the low cost, ease of use and ready availability.

Laboratory evaluation

The efficiency of whole-seed suspensions of *M.Stenopetala* and *M.Oleifera* was determined using model clay (Kaolin Light, BDH Ltd.), clay/bacteria and diluted sewage suspensions. Results have shown that both seed types are effective at removing turbidity from waters with high initial turbidities. The laboratory evaluation has highlighted problems in turbidity removal at low initial turbidities. With respect to the bacterial work, reductions in bacteria of between 90 to 99.9 per cent have been achieved.

Attempts to isolate the 'active ingredient' of *M.Stenopetala* have been made. Findings indicate that two water-soluble proteins (approximate molecular weight 8,000 Daltons) are responsible for the coagulation process, and purification has resulted in a freeze-dried extract of the water-soluble seed material. Work with the extract has shown that significantly lower dosages are required to give an equivalent performance to the whole seed in the reduction of both bacteria and turbidity. Investigations into the effect of the extract on bacteriophage (bacterial viruses) have also been carried out. An important finding is that not only is effective removal of bacteriophage possible, but the extract

© Linden Vincent

Surface sources are often highly turbid during the rainy season.

John P. Sutherland is a Research Assistant, Geoffrey K. Folkard a Lecturer in the Department of Engineering, and William D. Grant a Senior Lecturer in the Department of Microbiology at The University of Leicester, LE1 7RH.

appears to have an inhibitory effect, preventing replication of the bacteriophage. Further investigations of this effect are being carried out.

Field study

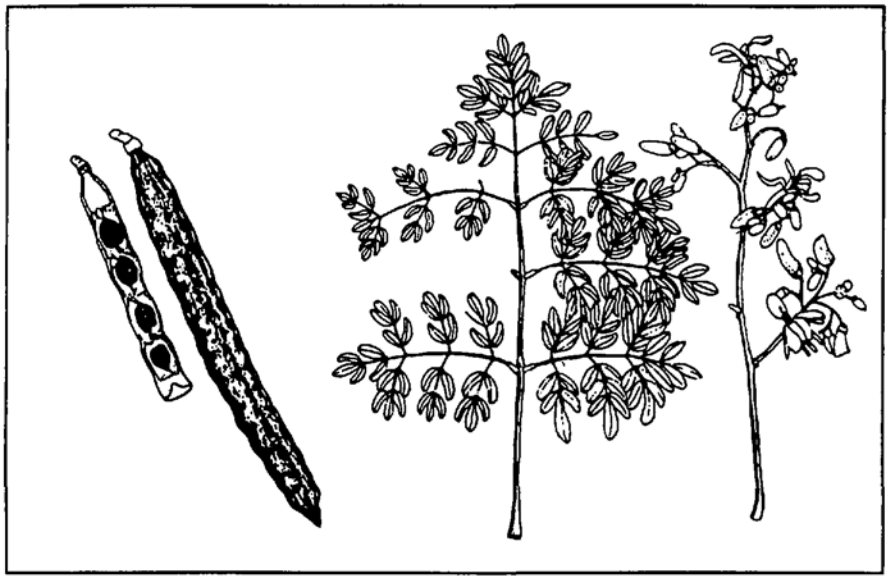
The principle aim of the field study was to evaluate the performance of the chosen natural coagulants in the flocculation of the turbid waters typically experienced in the rainy season.

The coagulants investigated were seeds of the trees *M.Stenopetala*, of Kenyan origin, and *M.Oleifera*, of Malawian origin. Information gathered from the National Herbarium of Malawi indicated that the growth of *M.Oleifera* was widespread throughout the country. In Chichewa, the national language of Malawi, the tree is called *chamwamba*. The trees are grown to provide saplings for 'live' fences and pods for consumption. Villagers use the leaves, flowers and immature pods in a relish called *ndiwo*. Mature green pods were found on sale in one of the Blantyre markets, and it was learnt that the Asian population use the pods as vegetables. Despite the widespread growth, the seeds are not used at present for traditional water-clarification purposes. Seed supplies for testing were obtained from trees growing outside the Great Hall of Chancellor College, Zomba.

Raw-water sampling sites were identified bearing in mind two main criteria. Firstly, the rivers and catchment areas should be as different from each other as possible, and secondly, the travelling distance to the source from the polytechnic was to be kept to a minimum. Following discussions with representatives from Blantyre Water Board (BWB) and the Ministry of Works and Supplies (MWS), it was decided that sampling would take place at Walker's Ferry treatment plant, under the control of BWB, and at Mwanza and Thyolo water-treatment plants, under the control of the MWS.

From each water source a 40 litre sample was collected. Before laboratory testing, basic water-quality analysis of the raw waters was carried out. Sometimes confirmatory water-quality analysis was carried out by BWB. Total counts and presumptive coliform counts were carried out using the Paqualab portable membrane-filtration and incubator apparatus.

The effectiveness of *M.Oleifera* and *M. Stenopetala* as whole seed additions were examined for all waters, and then these results were compared with those obtained for alum. Preliminary work was carried out using the freeze-dried extract of the *M.Stenopetala*; previous work indicated that the extract would require lower dosages than the whole seed to achieve equivalent clarification. In fact, although efficient clarification was achieved, the doses required were considerably higher than for the whole seed. This was at variance with data obtained previously for laboratory suspensions. The reasons for this phenomenon are as yet unknown, although it is possible that there were problems with production scale up and storage.



The pods (left), leaves (centre) and fruit of Moringa Oleifera. *(Diagram from* Common Trees of Puerto Rico and the Virgin Islands, *Little and Wadswort, Washington DC, USA, 1964)*

Co-coagulation

As a result of the problems associated with the use of the extract a novel approach was tried in which approximate equal concentrations of alum and *M.Oleifera* whole seed were

mixed together and used as the coagulant. Although investigations into the use of *M.Oleifera* as a coagulant aid have been previously carried out the observed effects of the above procedure do not appear to lend themselves to the traditional theories concerning coagulant-aid systems. As a result the procedure has been termed co-coagulation. Experiments to optimize the co-coagulant procedure were based on preliminary determination of optimum alum dose and subsequent use of *M.Oleifera* and alum to produce maximum savings in the concentration of the latter.

The results using whole-seed suspensions on raw waters have shown good correlation with those obtained for model suspensions. Both seed types gave equivalent, and in some cases superior performance to that of alum in the clarification of highly turbid waters. Additionally, floc formation and settling rates observed at high turbidities were similar to those for alum. For the Thyolo source water, with an initial turbidity of 150 NTU, coagulation with doses of 40mg/l of either alum or moringa seed resulted in turbidities of about 10mg/l. Similar results were obtained by co-coagulation with 15mg/l alum plus 25mg/l moringa seed. There was an unusual alum response here which is considered to be a result of the pH dependency of alum coagulation. Increased doses of alum gave increased turbidities, unlike the seeds, thus indicating an advantage of using the seeds.

For the Mwanza source water, with an initial turbidity of 1800 NTU, coagulation with doses of 75mg/l of either alum or moringa seed resulted in turbidities under 10mg/l. Co-coagulation with 25mg/l alum plus 50mg/l moringa seed gave turbidities well under 10mg/l.

Results for low-turbidity waters indicate a limit to the effectiveness of seed usage alone. For Mwanza and Thyolo low-turbidity samples, flocculation occurred but the flocs formed were small and light and did not settle quickly. These findings agree with previous work.[3] However, for the Walker's Ferry sample the flocs formed were large and relatively fast settling, contrary to previous findings. It is believed that the higher ionic content of the Walker's Ferry sample would account for this.

A renewable natural resource

The use of *M.Oleifera* in conjunction with alum to produce an effect termed co-coagulation gives dramatic improvements in flocculation ability and floc characteristics even at low turbidities. The procedure generates floc formation and settling rates similar to alum although, unlike alum, the floc produced using this system have a more uniform size. This results in even settling and a reduced sludge volume following settling. Further it is believed that this uniformity of size would lead to more effective floc blanket formation in upward flow clarification. The results obtained have shown that significant reductions in alum usage in the range 50-80 per cent can be made using the co-coagulation procedure. At high turbidities the need for alum may be eliminated, the whole seed giving equivalent or better performance. For many developing countries, imported alum is the major cost element in the provision of potable water. Malawi currently spends in excess of £220,000 per annum on importing alum. The use of the seeds, either alone or in conjunction with alum, for the large-scale treatment of raw waters would have two main implications. Firstly, the provision of a renewable natural resource that would reduce both foreign exchange expenditure and the dependency on foreign supplies. Secondly, success on the large scale would promote the introduction of the seeds for rural applications. The introduction of the seeds for large-scale treatment is considered viable.

The limited bacterial data has indicated that alum is more effective at removing bacteria from raw waters. However, because of problems encountered with the analysis, no firm conclusions can yet be drawn.

The main thrust of new work, again funded by the ODA, will be the practical introduction of *M.Oleifera* seeds, either in whole-seed or extract form, to existing low-volume treatment works in Malawi as co-coagulants with alum.

This work will include cultivation on an appropriate scale, the development of a cost effective method of seed processing and storage, an investigation of the active seed constituents on microbial and viral activity, and the feasibility of gene cloning.

Acknowledgement

The authors wish to acknowledge the financial assistance given by the Overseas Development Administration, and the co-operation and assistance of the Polytechnic of Malawi, the Ministry of Works and Supplies and Blantyre Water Board without whom this project would not have been possible.