13th WEDC Conference

Rural development in Africa
Malawi: 1987

Natural coagulants in water clarification

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ABSTRACT

Powdered seed suspensions of the Moringa oleifera tree have proved effective as a primary coagulant to clarify a stable kaolinite suspension. Acting as a cationic polyelectrolyte optimum minimum dosage to achieve maximum turbidity removal have been determined over a range of initial turbidity values (50-550NTU). The weight ratio of seed dosage to clay concentration appears independent of initial clay concentration. A field usable dissolved air flotation system has been developed. This technique, when applied to a kaolinite/bentonite model suspension, produced clear water in minutes as opposed to hours for conventional sedimentation. Topics for further investigation are outlined.

INTRODUCTION

Recent figures from the World Health Organisation reveal that when population growth is taken into account, more people will be without access to safe drinking water in 1990 than at the beginning of the decade. Of the 2000 million people currently without safe supplies, some 80% live in relatively small rural communities. In such situations many people draw water for drinking purposes from surface derived sources. For a riparian population in the rainy season, these sources are highly turbid and on occasions exhibit indicator bacterial concentrations similar to weak sewage.

Against this background, household treatment systems have an important role to play in providing aesthetically acceptable and bacteriologically safe drinking water. Individual communities suitably motivated, educated, trained and convinced of the benefits of applying basic water treatment practices will advance, perhaps centralising to a degree their individual efforts at achieving a wholesome water.

The use of chemicals is not generally considered to be appropriate to rural water treatment in developing countries. A proven alternative, however, is the use of indigenous plant derived materials to effect destabilisation of the suspended material. Rapid, effective destabilisation of the colloidal material with its associated bacteria followed by subsequent removal of the formed floc is of primary importance.

MORINGA OLEIFERA AS A PRIMARY COAGULANT

A remarkable number and variety of natural materials have been examined for their coagulating properties spontaneously and systematically by village inhabitant and research worker alike. Suspensions of seed powder from the tree, Moringa oleifera Lam. have been shown to be particularly effective as both a primary coagulant and as a coagulant aid for water clarification over a wide range of turbidities. A native of the sub-Himalayan regions of north west India, M.oleifera is now under cultivation in the tropical areas of Asia, Africa, Asia and South America as a valuable multi-purpose tree (ref.1)

Although much work has been done it is difficult to cross correlate results from the various studies on the use of natural coagulants in general and M.oleifera in particular. Individual studies have been conducted on very specific raw and synthetic test waters with many important parameters unstated. This paper reports on preliminary findings of a three year research programme with the overall objective to optimise the use of natural coagulants to remove suspended solids and associated indigenous bacteria. The programme includes laboratory work using chemically defined water and extensive field studies at mid term on natural waters.

Experimental Work

The work presented is based on model suspensions of kaolin (BDH, grade light) in deionised water with stated additional constituents. This clay mineral is commonly found in weathered tropical soils. The use of synthetic turbid suspensions based on kaolin are well established yielding treatment characteristics which are similar to river derived samples (ref.2). Treatment trends can be established under controlled conditions with interfering components of natural waters introduced in subsequent tests.

Pre-dried and weighed quantities of the clay were wetted for 24 hours and stock/working solutions prepared daily by dilution and rapid mixing at 6000 r.p.m. Figure 1 shows the relationship between turbidity and suspended solids concentration for the test water.

Apart from the origin and physical size of the suspended mineral particles, chemical constituents of the water influence the surface electrostatic stability of the particles. In particular the presence and subsequent adsorption of the divalent ions of calcium and magnesium may destabilize a suspension. In contrast, the presence of humic substances have been reported to increase the stability of certain substances (ref.2). Table 1 indicates the stability characteristics of the test water.

Seed suspensions are prepared by crushing preweighed kernel material with a pestle and mortar. Approximately 15mℓ of deionised water is then added and the suspension agitated.

The active fraction of the M.oleifera seed effecting coagulation has been determined to act as a cationic polyelectrolyte having little or no effect on residual pH and alkalinity (ref.3). For a range of initial turbidities viz. 50, 250, 400 and 550 NTU the optimum minimum seed dosage to achieve maximum clarification was achieved by a series of standard jar tests (rapid mixing for 2 minutes at 200 r.p.m. followed by slow mixing for 10 minutes at 20 r.p.m.) Samples, carefully extracted from a depth of 25mm below the water surface were subjected to turbidity measurement (Hach 2100A).

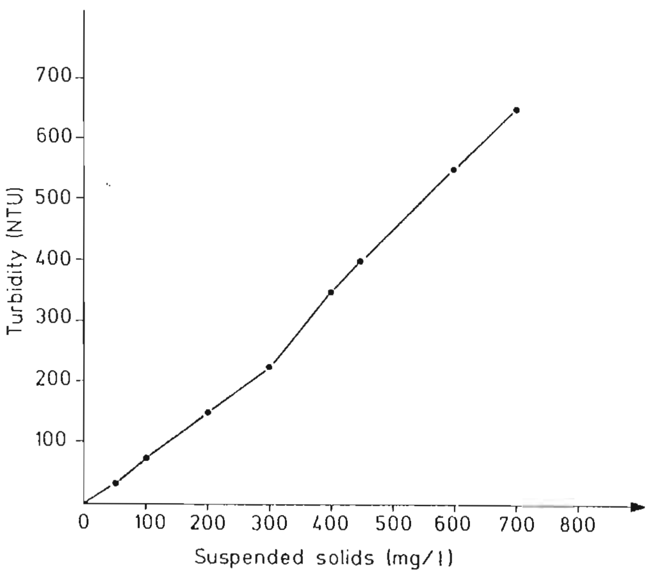

Figure 1 Correlation between suspended solids concentration and turbidity for the model kaolin suspension.

Figure 2 shows results of the 550 NTU initial turbidity samples. Data points represent average values of replicates. This takes into account the inherent variability in the nature and preparation of the seeds.

This typically shows that the minimum residual turbidity is maintained over a wide seed dosage range. Proprietary cationic polymers generally exhibit a more distinct and restricted optimum dosage range with larger or smaller dosage giving incomplete removal. However some raw waters have not shown such "overfeed" problems (ref.4).

Figure 3 indicates the stochiometric relationship obtained between minimum optimum seed dosage and clay concentration through the range studied. The weight ratio of seed dosage to clay concentration appears independent of the initial clay concentration. A similar relationship has been reported using a proprietary cationic polymer to destabilise a far more dilute kaolin suspension in the range 15-80 mgℓ$^{-1}$ (ref.5).

TABLE 1. Stability characteristics of the model kaolin suspension

	Sample turbidity (NTU)			
Suspended Solids concentration (mgℓ$^{-1}$)	at time 0	after 1 hr.	after 2 hrs.	after 3 hrs.
50	35	35	30	30
100	75	70	70	65
200	150	130	125	125
300	225	225	200	200
400	350	350	350	325
450	400	375	400	400
600	550	525	475	450
700	650	650	650	625
800	1000	900	850	800
	Sample turbidity (NTU)			
Chemical Addition	at time 0	after 1 hr.	after 2 hrs.	after 3 hrs.
CONTROL	550	550	500	550
400mgℓ$^{-1}$ $NaHCO_3$	550	500	450	500
40mgℓ$^{-1}$Ca	550	50	30	30
10mgℓ$^{-1}$Ca	550	55	40	40
400mgℓ$^{-1}$ $NaHCO_3$ + 40mgℓ$^{-1}$Ca	550	150	100	100
400mgℓ$^{-1}$ $NaHCO_3$ + 10mgℓ$^{-1}$Ca	550	450	350	300

If a similar relationship can be established for a natural raw water then this may prove to be a valuable treatment guide. In the field situation, suspended solids concentration could be cross correlated by simplified turbidity measurements.

DISSOLVED AIR FLOTATION

The application of dissolved air flotation (DAF) as a unit process for the developing world may at first seem incongruous. However figure 4 shows a low cost working system with a plastic carbonated water bottle acting as the saturator vessel.

At 20°C, with the saturator pressurised to 5.5 atmospheres using a bicycle pump, almost 6 times the volume of air is in solution compared to that at 1 atmosphere. This volume is released in the form of microscopic air bubbles when the flow enters the flotation vessel under atmospheric pressure. The bubbles enmesh with the light floc, reduce the apparent density and a relatively high upflow separation velocity results.

A compact, free-draining sludge layer quickly develops on the top surface of the flotation vessel. Figure 5 gives results of applying DAF in conjunction with M.oleifera seed suspensions to a synthetic raw water (kaolin/bentonite mix in distilled water) of initial turbidity 100 NTU. DAF yielded a residual value of 3.5 NTU after only 10 minutes compared to 20 NTU after 60 minutes of sedimentation. Figure 5 also indicates that it may be possible to achieve clarification at reduced seed dosages.

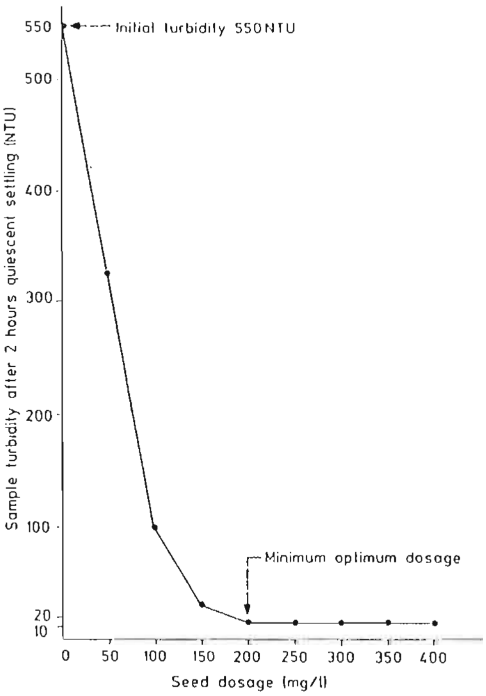

Figure 2 Relationship between applied seed dosage and residual turbidity after 2 hours settlement

FUTURE WORK

Under favourable conditions, clarification by natural coagulants can be regarded as a complete treatment measure in its' own right. However investigations of the removal of bacteria have yielded disappointing results since the total count of indigenous bacteria in treated waters is initially reduced, but does not decrease thereafter concomitantly with turbidity. Waters seeded with indicator organisms show a similar trend in respect of decrease of the indicator bacteria (ref.6).

The failure to completely remove bacteria may be due to secondary bacterial growth on nutrients in the seed preparation or may be due to the failure of small flocs to readily sediment unaided. Alternatively, bacteria may be released from larger flocs with time. Furthermore, there is no information as to the behaviour of viruses in so treated waters, and in view of the established transmission of certain viral diseases in drinking waters, knowledge of the fate of viral particles in treated waters is equally important. These aspects will be examined.

Alternatively coagulation could prove to be an effective low-cost pretreatment stage to household slow sand filter installations as reported (ref.7). Filter runs could be maintained when raw water turbidity exceeds 10-15 NTU.

Apart from slow sand filtration, other appropriate final disinfection options to be

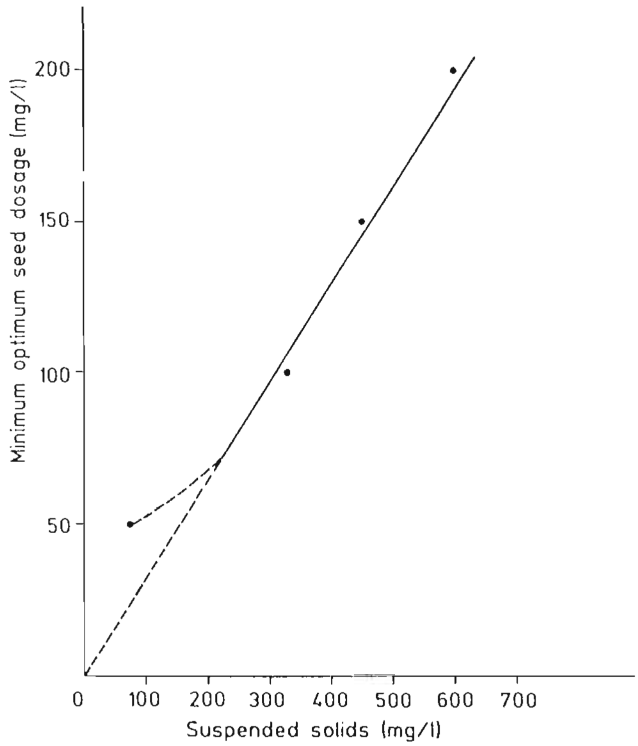

Figure 3 Correlation of clay concentration with minimum optimum seed dosage

investigated include exposing the clarified water to solar radiation and the inclusion of a metallic copper element in the storage vessel.

ACKNOWLEDGEMENTS

This paper reports on the initial findings of a three year research programme funded by the Overseas Development Administration.

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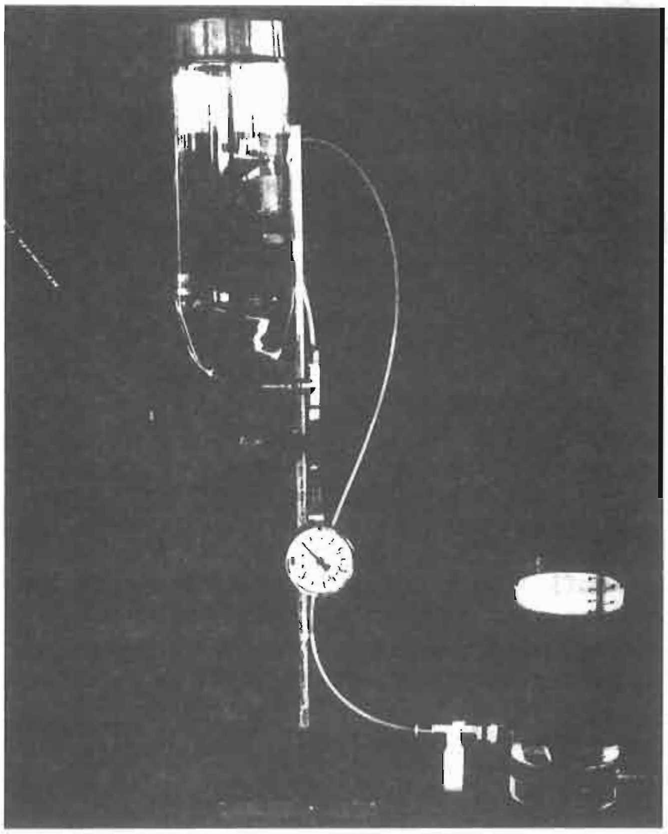

Figure 4 The low cost dissolved air flotation system

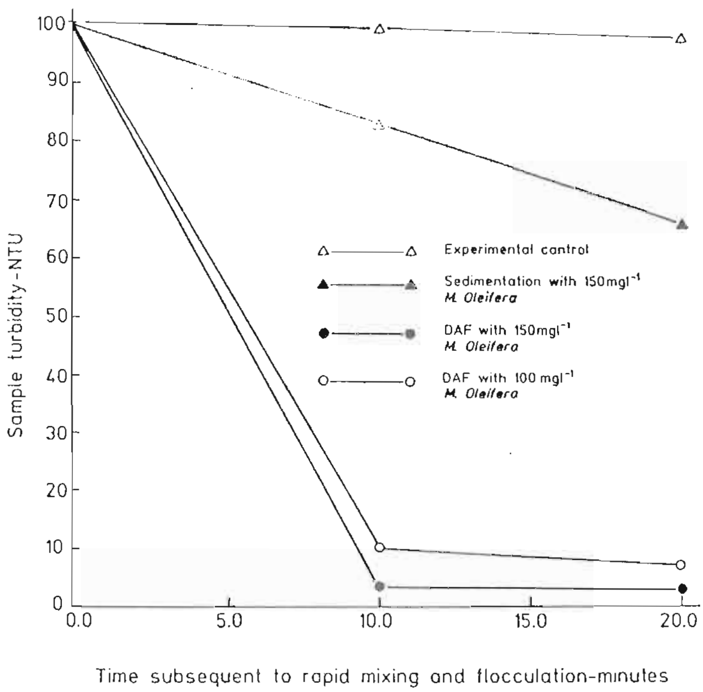

Figure 5 Comparison of dissolved air flotation and sedimentation for a kaolinite/ bentonite model suspension