African Journal of Agricultural Research Vol. 5(11), pp. 1256-1263, 4 June, 2010
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR09.600
ISSN 1991-637X © 2010 Academic Journals

Full Length Research Paper

Water treatment by sedimentation and slow fabric filtration using *Moringa oleifera* seeds

José E. S. Paterniani[1]*, Tulio A. P. Ribeiro[2], Márcia C. Mantovani[3] and Márcia R. Sant´anna[3]

[1]University of Campinas, Feagri/UNICAMP, CEP 13083-875, Campinas, SP, Brazil.
[2]University of Campinas, of hydraulic and irrigation, Feagri/UNICAMP, CEP 13083-875, Campinas, SP, Brazil.
[3]University of Campinas, Ceset/UNICAMP and Scientific Initiation scholarship holders at Feagri/UNICAMP, CEP 13083-875, Campinas, SP, Brazil.

Accepted 25 May, 2010

The main objective of this work was to evaluate the suitability and efficiency of a natural coagulant from *Moringa oleifera* seeds in treating high turbidity water in the processes of slow direct filtration and sedimentation. In developing countries such as Brazil, the technologies for water treatment shall enable people living in potable-water deficient regions to purify water in easy and self-sustainable ways and at a low cost as well. Within this proposition, a potential use of *M. oleifera* has been suggested in several previous studies. In this work, a flocculation device made of pet bottles plus three filters consisting of pet bottles and non-woven synthetic fabric was used in the water treatment by slow direct filtration. The water output to the filters was of approximately 4 m^3m^{-2} per day. The water treatment by sedimentation comprised a flocculation unit made of pet bottles and a sedimentation tank. Synthetic bentonite-water was used as the untreated water, which was chosen due to its proper qualitative characteristics for the experiments. The data demonstrated that the *M. oleifera* coagulant was efficient in the treatment of water with high turbidity (50 to 100 NTU) in the tested systems of slow filtration through synthetic non-woven fabric and of sedimentation.

Key words: *Moringa oleifera*, slow filtration, sedimentation, purification of water.

INTRODUCTION

In developing countries, particularly in the rainy season, the river water used for human consumption and for domestic use can be highly turbid, containing suspended matter in suspension, bacteria and other microorganisms. Each year, millions of children may die in those countries, victims of infections caused by unclean water. Therefore, such contaminants must be removed, as much as possible, before water consumption. Usually, water purification is done by adding chemical coagulants in a sequence of controlled treatments. Chemical coagulants, as Aluminum Sulphate, are not always available at a reasonable price to the populations of developing countries. In this case, the natural coagulants, generally of vegetable origin, are an alternative treatment for particle coagulation in the purification process of high turbidity water.

The *Moringa oleifera* belongs to the family Moringaceae, consisting of the genus *Moringa* only, which is composed of fourteen known species. Native to the Northern region of India, *M. oleifera* has been cultivated in several tropical countries. The seed pods are legume-like in appearance, but differently from the typical two-sided legumes, these pods are triangular and have a large number of seeds. Feasibility studies on the use of *M. oleifera* for water purification have been done in several countries by many researchers and institutions. “Due to the problem of world water deficit increasingly in

*Corresponding author. E-mail: pater@agr.unicamp.br. Tel: (55)19-35211019.

various parts of the world, mainly in arid and semi-arid regions such as northeastern Brazil, seeds moringa are very important to use of treatment water. Gerdes (1996) has declared that the moringa tree resist long dry periods producing flowers and fruits even with very few leaves. For Almeida et al. (1999) Moringa is a plant of great importance for the Brazilian Northeast and other regions of arid and semiarid regions of the planet. It survives under conditions of high water deficit, supports large variations in temperature, relative humidity and precipitation."

The *M. oleifera* is a tall tree up to 10 m height, with thick stalk and long-petiolated leaves, which are bipinnate with obovate folioles about 3 cm long. It has edible fruits and leaves, and the roots are described to have abortive properties (Corrêa, 1984). Recent findings have indicated *M. oleifera* triturated seeds as an alternative to purify water, at costs as low as a small fraction of the conventional chemical treatments. Regarding bacteria, such studies have reported a reduction of 90 - 99% of these microorganisms.

According to Leme (1982), the flocculation process is intended to agglutinate the coagulated particles by establishing contact among them and with other particles in the water. Agitation is used so that particle aggregates are increased in their size and density. Following the destabilization of the colloidal particles in the coagulation treatment, they can be clustered to form the so called flakes (Vianna, 2002).

The methods of filtration through sand layers started from the observation of the purity and clarity of underground water, which was attributed to the passage of water through natural pores (Azevedo Netto, 1987). In 1804, John Gibbd, cited by Azevedo Netto (1987), developed an experimental slow filter system in Paisley, Scotland, which was then used to purify water from the Thames River, aiming at no more than removing turbidity and solids in suspension. Within a short time, the slow filtration as a mean to purify water had reached European and American countries.

The slow filtration method always had some limitation, such as the affluent quality, whose turbidity should not be higher than 30 NTU. According to Bernardo (1999), the utilization of pre-treatment units is indeed fundamental for the suitability and efficiency of slow filtration applied to high turbidity water. The use of pre-filters preceding the slow filtration originated the multi-stage filtration and turned the slow filtration into one of the most practicable technologies, mainly for small rural communities. Thus, new pre-treatment techniques, as for instance the simple sedimentation using natural coagulants in conjunction with slow filtration, can make the application of this technology even more flexible.

The objective of the present work was to evaluate the suitability and efficiency of a natural coagulant obtained from seeds of *M. oleifera* used in treating high turbidity water in the processes of slow direct filtration and sedimentation.

MATERIALS AND METHODS

An experimental pilot device was built in the laboratory of sanitation at the Agricultural Engineering Faculty of the State University of Campinas, Campinas, SP, Brazil, during the period of August, 2005 to June, 2006. The efficiency of the coagulant extracted from *M. oleifera* seeds was evaluated in two independent procedures of water treatment, slow direct filtration through blankets made of non-woven synthetic fabric and simple sedimentation.

A jar test device was used as coagulation unit, agitating at 400 s^{-1} per 1 min. Following coagulation, the water was flowed on a trough toward a flocculation unit of gravel layer and ascending flux. Initially, two equivalent flocculation devices were tested, which were made of pet bottles and a gravel layer of 700 mm. The height of each flocculation apparatus was 900 mm and they varied only in gravel granulometry, from 4 to 10 mm and from 20 to 38 mm, being respectively, named as smaller flocculator and larger flocculator. They were independently tested in the sedimentation assays and the most efficient one was chosen to carry out the slow direct filtration experiment.

In the slow direct filtration assays, the water flowing from the flocculation unit was directed to a set of three filters. The water was sampled for analysis, following a predetermined timetable. As for the sedimentation assays, the water was flowed from the flocculation unit directly into a sedimentation tank and sampled as well.

The filters were built with pet bottles of 100 mm diameter and 700 mm height. Each filter contained 100 mm of filtering medium, consisting of non-woven synthetic fabric blankets of three diverse thicknesses, which were named Filter 1 (150 gm^{-2}), Filter 2 (300 gm^{-2}) and Filter 3 (600 gm^{-2}). A fluxometer was installed in the water exit of each filter in order to maintain a constant filtration ratio of approximately 4 m^3m^{-2} per day. A volume of 3 liters of water from the flocculation unit was simultaneously distributed to each of the three filters. The fluxometers remained closed until the water was equally distributed inside the filters. Afterwards, 150 ml of water were sampled from each filter at time zero (t0) and at 30 min (t30) of filtration.

In the sedimentation assays, the coagulation and flocculation procedures were the same as in the slow filtration experiment, and the sedimentation tank was a plastic container with capacity of 3 L. A calibrated volumetric pipette was used to sample the water, always at the same position of the decantation device, at time zero (t0), 10 min (t10) and 30 min (t30) of sedimentation. An illustration representing the pilot apparatus built for the direct filtration and sedimentation assays is shown in Figure 1.

The water purification assays were performed using raw water with initial turbidity values of approximately 50 NTU and 100 NTU. In order to reach the proper turbidity the raw water was prepared from a bentonite suspension. Thus, the desired water qualitative characteristics were achieved and maintained as a standard in all of the experiments.

The coagulation solution was prepared with *M. oleifera* seeds removed from recently harvested dry seed pods. The seed coat and wings were removed and the seeds were ground to powder in a mortar and pestle. Coagulant compounds were extracted by adding water to the powdered seeds, under agitation, according to the methodology described by Ndabigengesere and Narasiah (1996), Ndabigengesere et al. (1995), Muyibi and Okuofu (1995) and Muyibi and Evison (1995). Based on literature data, the tested coagulant solutions were 150, 300 and 500 mgL^{-1} in the 100 NTU turbidity assays, and 75, 150 and 300 mgL^{-1} in the 50 NTU turbidity assays.

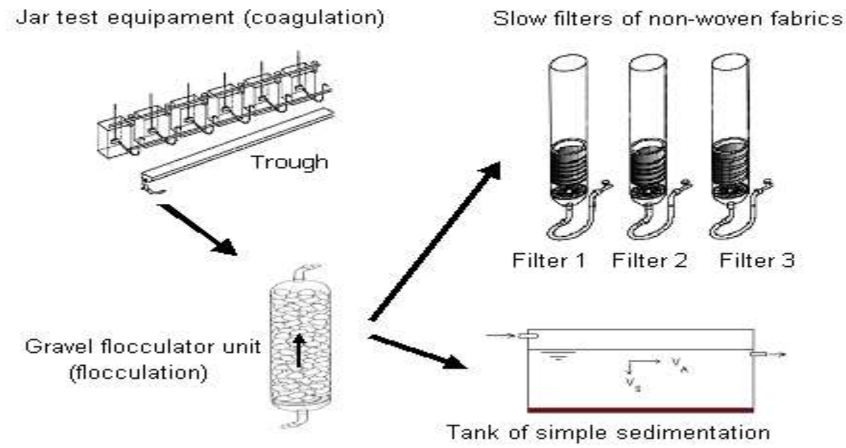

Figure 1. Illustration of the slow direct filtration and sedimentation procedures.

Table 1. Efficiencies (%) of the larger and smaller flocculation devices in removing water turbidity by sedimentation, assessed at time zero (t0), 10 min (t10) and 30 min (t30) of sedimentation as a function of the treatments with 150, 300 and 500 mgL^{-1} coagulant from *M. oleifera* seeds. The initial raw water turbidity was 100 NTU.

Sample (duration time of sedimentation)	% of water turbidity removal in the larger flocculator			% of water turbidity removal in the smaller flocculator		
	150 mgL^{-1}	300 mgL^{-1}	500 mgL^{-1}	150 mgL^{-1}	300 mgL^{-1}	500 mgL^{-1}
t0 (min)	29	66	71	22	60	3
t10 (min)	35	72	91	41	74	86
t30 (min)	41	75	92	43	78	88

Water turbidity and apparent color were the quantitative parameters used to evaluate the efficiency of the water purification procedures and the quality of water produced. The measurements turbidity was made using a turbid meter digital and apparent color a spectrophotometer. Additionally, the pH, the time duration of the sedimentation and the filtering ratio in the slow filtration assays were monitored during the experiments. The pH measurements were made using a digital pH meter. The efficiency of the flocculation system was estimated in the sedimentation assays, based on turbidity removal and apparent color reduction, as well as velocity gradient and camp number. The velocity gradient was calculated according to Vianna (2002) using equation 1.

$$G = (g*h / v*t)^{1/2} \quad \ldots\ldots(1)$$

Where:
G = velocity gradient (s^{-1})
g = acceleration due to gravity (m^2 s^{-1})
h = sum of the sum of the losses at the entrance and along the compartment (m)
v = kinematic viscosity (m^2 s^{-1})
t = period of detention in the compartment (s)
The number of camp was also determined in accordance with Vianna (2002) using equation 2.

$$\text{Camp number} = G.\ t \quad \ldots\ldots(2)$$

The analysis, measurements and calibration of equipment used this search, following recommendations of the standard methods for the examination of water and waste water. (Apha, 1985). For sedimentation, assays were performed three repetitions with three different doses in three time intervals, totaling 27 tests. The same procedure was used for testing filtration system, where instead of three times of sedimentation were used three fabrics with different gramature.

RESULTS AND DISCUSSIONS

Comparative assays of the gravel flocculation units

As shown in Table 1, the 500 mgL^{-1} coagulation solution from *M. oleifera* seeds was the most efficient treatment to reduce water turbidity in the 100 NTU assays, in both flocculation units. In this treatment with the 500 mgL^{-1} coagulation solution, the water turbidity reduction at 30 min of sedimentation was 92% in the larger flocculator and 88% in the smaller flocculator. At time zero, the larger flocculator showed a turbidity removal of 71%, which was much higher then the 3% turbidity removal observed in the smaller flocculator (Table 1). As for the water apparent color, the larger flocculator and the smaller flocculator showed reductions of 94 and 90%, respectively, both measured at 30 min of sedimentation. These results of apparent water color removal were the best in the assays using raw water with initial turbidity of 100 NTU (Table 2).

The results obtained in the sedimentation assays using

Table 2. Efficiencies (%) of the larger and smaller flocculation devices in removing water apparent color, as assessed at time zero (t0), 10 min (t10) and 30 min (t30) of sedimentation as a function of treatments with 150, 300 and 500 mgL^{-1} coagulant from *M. oleifera* seeds. The initial raw water turbidity was 100 NTU.

Sample (duration time of sedimentation)	% of water apparent color removal in the larger flocculator			% of water apparent color removal in the smaller flocculator		
	150 mgL^{-1}	300 mgL^{-1}	500 mgL^{-1}	150 mgL^{-1}	300 mgL^{-1}	500 mgL^{-1}
t0 (min)	40	72	78	30	68	20
t10 (min)	46	78	92	48	81	89
t30 (min)	51	80	94	51	83	90

Table 3. Efficiencies (%) of the larger and smaller flocculation devices in removing turbidity of raw water by sedimentation, assessed at time zero (t0), 10 min (t10) and 30 min (t30) of sedimentation as a function of treatments with 75, 150 and 300 mgL^{-1}coagulant from *M. oleifera* seeds. The initial raw water turbidity was 50 NTU.

Sample (duration time of sedimentation)	% of water turbidity removal in the larger flocculator			% of water turbidity removal in the smaller flocculator		
	75 mgL^{-1}	150 mgL^{-1}	300 mgL^{-1}	75 mgL^{-1}	150 mgL^{-1}	300 mgL^{-1}
t0 (min)	35	40	0	27	9	0
t10 (min)	43	69	50	42	57	56
t30 (min)	52	80	70	51	72	71

Table 4. Efficiencies (%) of the larger and smaller flocculation devices in removing the water apparent color, as assessed at time zero (t0), 10 min (t10) and 30 min (t30) of sedimentation as a function of treatments with 75, 150 and 300 mgL^{-1} coagulant from *M. oleifera* seeds. The initial raw water turbidity was 50 NTU.

Sample (duration time of sedimentation)	% of water apparent color removal in the larger flocculator			% of water apparent color removal in the smaller flocculator		
	75 mgL^{-1}	150 mgL^{-1}	300 mgL^{-1}	75 mgL^{-1}	150 mgL^{-1}	300 mgL^{-1}
t0 (min)	40	38	0	37	20	0
t10 (min)	49	71	53	48	63	56
t30 (min)	57	79	69	58	73	71

raw water with initial turbidity of approximately 50 NTU are shown in Tables 3 and 4. In both larger and smaller flocculation devices, the 150 mgL^{-1} coagulant solution was the most effective in removing the water turbidity and apparent color, as assessed at 10 min and 30 min of sedimentation. In addition, the 30 min of sedimentation was the most efficient in all treatments, resulting in 80% turbidity removal in the larger flocculator and 72% in the smaller flocculator. The results of the 150 and 300 mgL^{-1} coagulant treatments in the smaller flocculator were quite similar to each other at 10 and 30 min of sedimentation. As for water apparent color removal, the larger flocculator was again the most effective (Table 4).

The detention time average in the larger flocculator was 2 min and 30 sec while in the smaller flocculator was 2 min and 10 sec. In the larger flocculator, the velocity gradient G was 97.43 s^{-1} and camp was 14,614. As for the smaller flocculator, the velocity gradient was 118.7 s^{-1} and camp was 15,431. As considered by Vianna (2002), for an ideal slow mixture the required velocity gradient G is 85 s^{-1} and the camp is 16,000 to 15,000.

Therefore, the results obtained in both flocculation units demonstrated that their parameters are close to those considered ideal for a slow mixture. The larger flocculator was the most efficient, mainly regarding turbidity and color removal, and so it was chosen as the flocculation device for the following experiments. The G value in the larger flocculator was closer to 85 s^{-1}, which is considered to promote a slower passage through the granular medium interstices leading to a better flocculation (Vianna, 2002).

The sedimentation process

The simple sedimentation of the coagulated suspension of 100 NTU water showed that the treatment using 500 mgL^{-1} of *M. oleifera* coagulant was the best for removing both turbidity and apparent color. As for the 50 NTU assays, the 150 mgL^{-1} treatment was the best for both

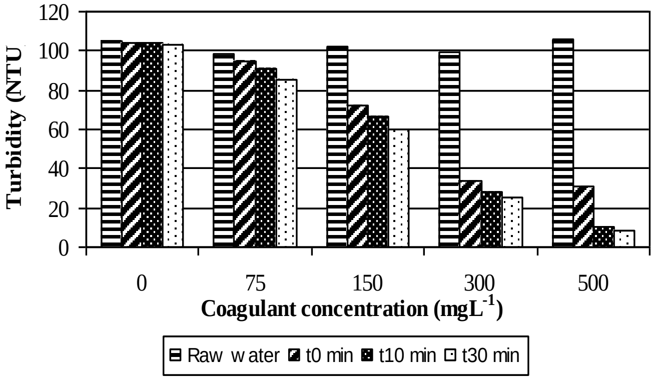

Figure 2. Turbidity of the raw water (100 NTU) and of the outflow water from the larger flocculator, at times t0, t10 and t30 min as a function of diverse concentrations of *M. oleifera* coagulant.

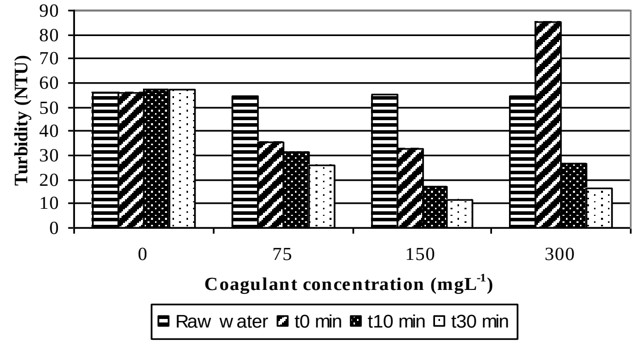

Figure 4. Turbidity values of the raw water (50 NTU) and of the outflow from the larger flocculator, in the t0, t10 and t30 min as a function of diverse coagulant concentrations.

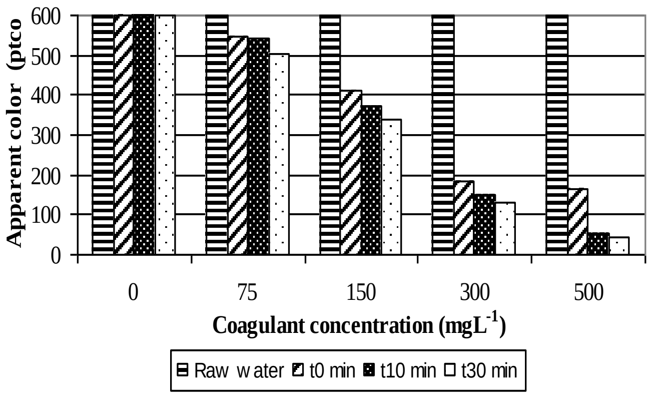

Figure 3. Apparent color of the raw water (100 NTU) and of the outflow water from the larger flocculator, at t0, t10 and t30 min as a function of diverse concentrations of the *M. oleifera* coagulant.

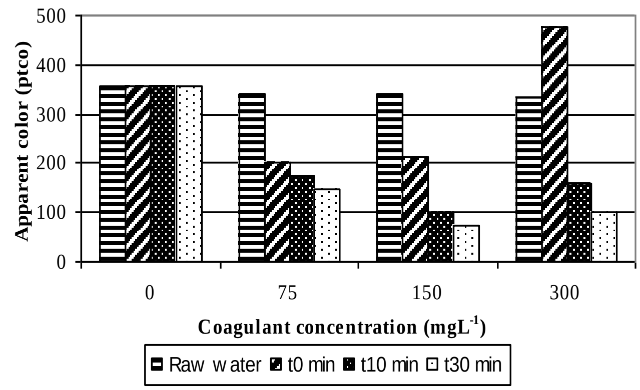

Figure 5. Apparent color values of the raw water (50 NTU) and of the outflow from the larger flocculator, in the t0, t10 and t30 min as a function of diverse coagulant concentrations.

turbidity and apparent color removal. The larger flocculator with the 500 mgL^{-1} coagulant solution resulted, at 30 min of sedimentation, in a reduction of 92 and 94% in the water turbidity and apparent color, respectively (Figures 2 and 3).

Figure 4 and 5 shows the results for turbidity and apparent color removal from the 100 NTU water in the larger Flocculator assays. The 150 mgL^{-1} coagulant treatment resulted in the highest water purification, reducing 80% turbidity and 79% apparent color.

At time zero of the 300 mgL^{-1} treatment, thus immediately after filling up the sedimentation device, there was an obvious increase of turbidity and color comparatively to the initial raw water values. Such increase was attributed to an addition of particles in suspension or dissolved in the water, which were inherent to the *M. oleifera* coagulation extract itself. A filtration of the coagulant extract previously to the coagulation can avoid this higher initial turbidity and color. However, that does not interfere with the experimental procedures and results. This previous filtration was not used in the experiments due to practical reasons. In the following 10 min of sedimentation, these initial high turbidity and color were drastically decreased to about 50% of the untreated water values. Figures 4 and 5 illustrate, respectively, turbidity and color removal by simple sedimentation of the 50 NTU raw water submitted to diverse coagulant concentrations. The 150 mgL^{-1} coagulant treatment was the most efficacious in removing the water turbidity and color (Figures 4 and 5).

The slow direct filtration process

In the slow direct filtration experiment, the flocculation device and the coagulant concentrations were equal to those used in the simple sedimentation assays. The two raw water standards (50 and 100 NTU) prepared from a bentonite suspension were the same as those used in the

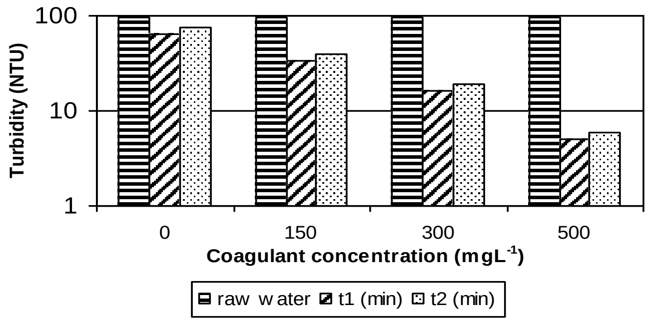

Figure 6. Turbidity reductions in filter 1 at time zero (t1) and at 30 min (t2) of filtration of raw water of approximately 100 NTU treated with diverse coagulant concentrations.

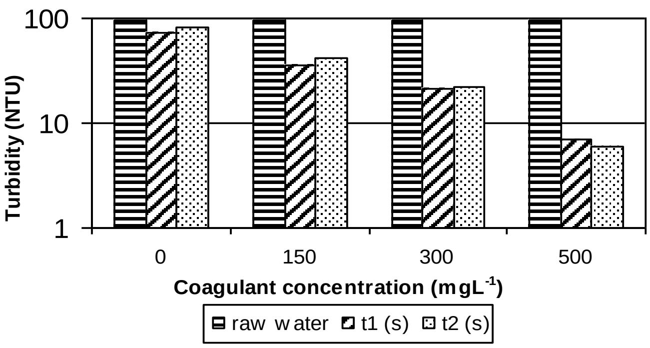

Figure 7. Turbidity reduction in filter 2 at time zero (t1) and at 30 min (t2) of filtration of raw water of approximately 100 NTU treated with diverse coagulant concentrations.

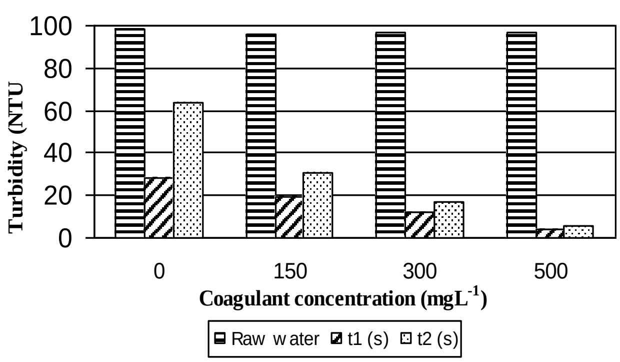

Figure 8. Turbidity reduction in filter 3 at time zero (t1) and at 30 min (t2) of filtration of raw water of approximately 100 NTU treated with diverse coagulant concentrations.

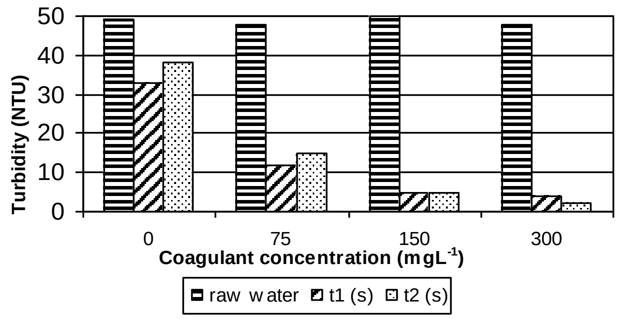

Figure 9. Turbidity reduction in filter 1 at time zero (t1) and at 30 min (t2) of filtration of raw water of approximately 50 NTU treated with diverse coagulant concentrations.

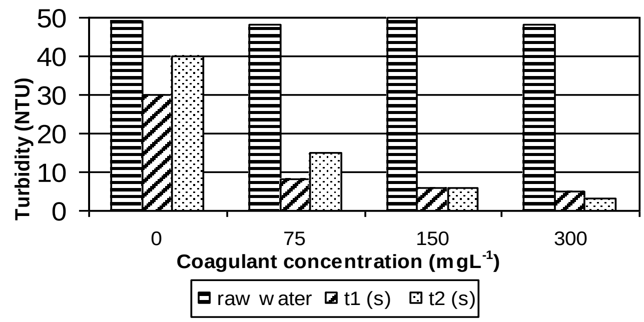

Figure 10. Turbidity reduction in filter 2 at time zero (t1) and at 30 min (t2) of filtration of raw water of approximately 50 NTU treated with diverse coagulant concentrations.

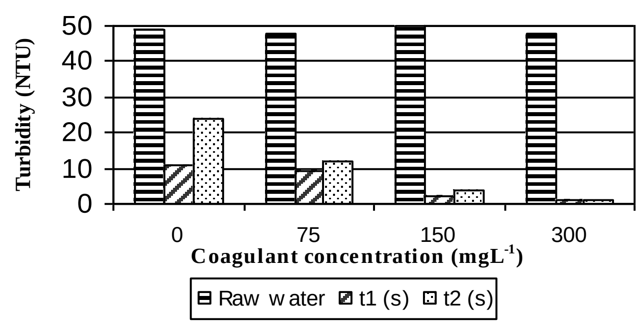

Figure 11. Turbidity reduction in filter 3 at time zero (t1) and at 30 min (t2) of filtration of raw water of approximately 50 NTU treated with diverse coagulant concentrations.

simple sedimentation procedures. The three non-woven synthetic fabric (150, 300 and 600 gm^{-2}) allowed to evaluate quantitatively the effects of filter blanket thickness on the removal of turbidity and apparent color from water previously treated by coagulation and flocculation. Figures 6 to 17 shows the results from the slow filtration assays regarding reduction of turbidity and apparent color in raw water (100 and 50 NTU) treated with *M. oleifera* coagulant. As shown in Figures 6 to 11, the three tested filters were obviously efficacious in

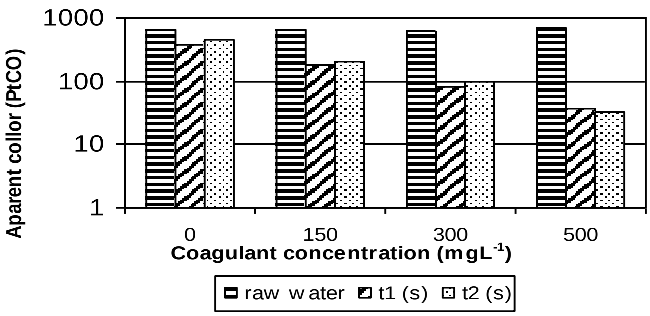

Figure 12. Apparent color reduction in filter 1 at time zero (t0) and at 30 min (t30) of filtration of raw water of approximately 100 NTU treated with diverse coagulant concentrations.

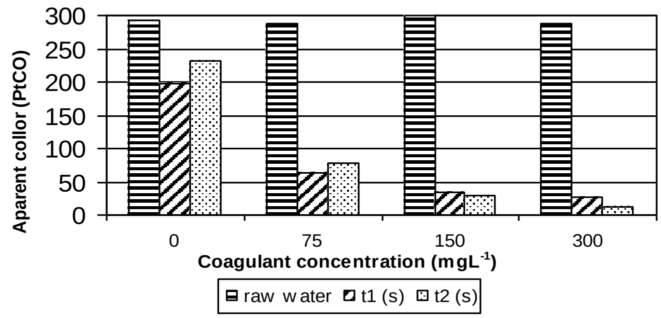

Figure 15. Apparent color reduction in Filter 1 at time zero (t0) and at 30 min (t30) of filtration of raw water of approximately 50 NTU treated with diverse coagulant concentrations.

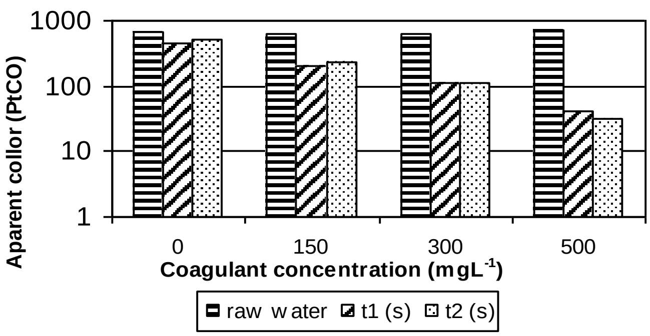

Figure 13. Apparent color reduction in filter 2 at time zero (t0) and at 30 min (t30) of filtration of raw water of approximately 100 NTU treated with diverse coagulant concentrations.

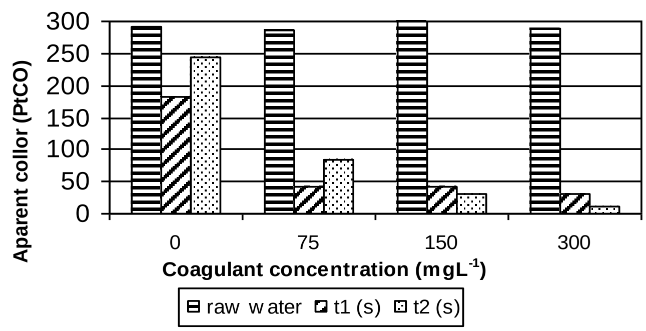

Figure 16. Apparent color reduction in filter 2 at time zero (t0) and at 30 min (t30) of filtration of raw water of approximately 50 NTU treated with diverse coagulant concentrations.

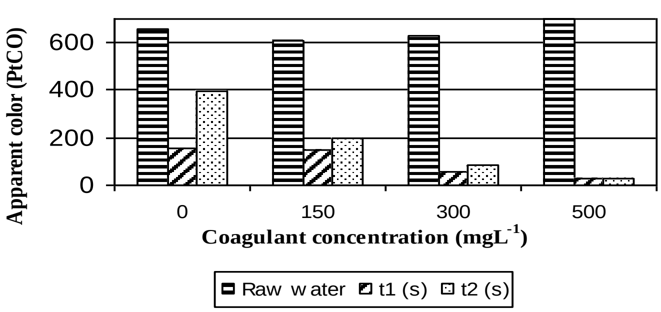

Figure 14. Apparent color reduction in filter 3 at time zero (t0) and at 30 min (t30) of filtration of raw water of approximately 100 NTU treated with diverse coagulant concentrations.

removing turbidity. Filter 3 (600 gm^{-2}) was slightly more efficient for both 50 NTU and 100 NTU raw water.The data shown in Figures 12 to 17 demonstrate once again the feasibility of the natural coagulant from *M. oleifera* in treating highly turbid water previously to slow filtration. The three filters efficiently removed apparent color in all treatments. The filtration efficiency was slightly higher in filter 3 (600 gm^{-2}) for both 100 and 50 NTU water turbidities.

The highest efficiencies of turbidity and apparent color reduction were associated to the increase of coagulant concentration. The highest concentrations of *M. oleifera* coagulant resulted in greater removal of turbidity and apparent color. The best condition to remove turbidity and apparent color of the raw water with 100 NTU was in filter 3 (600 gm^{-2}), using water treated with 500 mgL^{-1} of coagulant. As shown in Figures 8 and 14, in such condition there was a turbidity and apparent color reduction of approximately 96%.

As can be observed in Figures 11 and 17, the efficacy of filter 3 was confirmed in the assays with raw water of approximately 50 NTU. The data were similar to the assays using 100 NTU water, but the efficient filtration procedures required lower concentrations of the natural coagulant. In these assays, the turbidity was reduced in 94% and the apparent color was reduced in 92% using the 150 mgL^{-1} coagulant concentration to treat 50 NTU water. As for the 300 $mg.L^{-1}$ coagulation solution, there

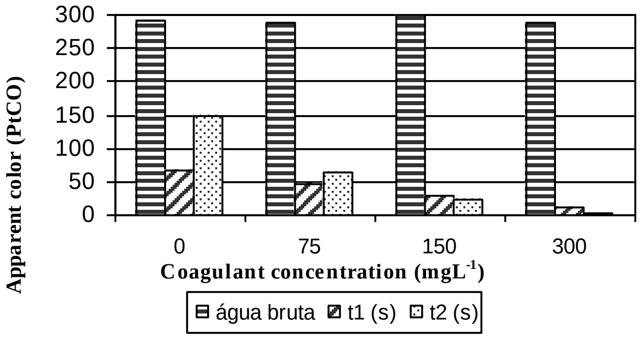

Figure 17. Apparent color reduction in filter 3 at time zero (t0) and at 30 min (t30) of filtration of raw water of approximately 50 NTU treated with diverse coagulant concentrations.

was approximately 98% removal of the turbidity and apparent color. These data indicate that the concentration of the *M. oleifera* coagulant must be proportional to the raw water turbidity. Therefore, the higher the turbidity, the higher should be the natural coagulant concentration used in the turbid water purification.

Conclusions

The data on the efficiency of the coagulant extracted from *M. oleifera* seeds in the treatment of highly turbid water allowed for the following conclusions:

(a) The coagulant obtained from seeds of *Moringa oleifera* is efficient in treating water with turbidity in a range of 50 and 100 NTU, both for simple sedimentation and slow filtration in non-woven synthetic fabric.
(b) The highest averages of turbidity and apparent color reduction of 90% in the simple sedimentation and 96% in the slow filtration assays demonstrated that the evaluated water purification procedures using the natural coagulant treatment are feasible for practical use and at low costs.
(c) The granular flocculation units using gravel were efficient in flocculating particles in suspension in the highly turbid raw water.
(d) The greater the water turbidity, the greater the coagulant concentration, both for simple sedimentation and slow filtration.
(e) Non-woven synthetic of 600 gm^{-2} thickness were the most efficient in removing water turbidity, as well as apparent color.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge CNPq/PIBIC and SAE/Unicamp for scientific initiation scholarships to M. C. M. and to M. R. S., and CNPq for a fellowship on research productivity (Process: 303889/2005-5). This research was supported by Fapesp (Grant 03/07709-3).

REFERENCES

Almeida VM, Souto JS, Araújo LVC, Pereira FJM, Santos RV (1999). Composição química bromatológica da moringa (*Moringa oleifera Lam*) no semi-árido paraibano. In: Congresso Brasileiro de Medicina Veterinária, 26 Campo Grande, M.S. Anais.

American Public Health Association (1985). Standard methods for the examination of water and wastewater. 16. ed. Washington: APHA; AWWA; APCF p. 1268.

Azevedo NJM, parlatore AC, Rossin AC, Manfrini C, Hespanhol I, Campos JR, Povinelli J, Yaguinuma S (1987). Técnica de Abastecimento e Tratamento de Água, v.2. 3ªedição. Cetesb/Ascetesb p. 317 São Paulo.

Di Bernardo L, Brandão CCS, Heller L (1999). Tratamento de águas de Abastecimento por Filtração em Múltiplas Etapas. Abes/ Prosab. Rio de Janeiro p. 114.

Gerdes GO (1996). uso das sementes da árvore moringa para o tratamento de água turva. Fortaleza. Esplar p. 13.

Leme FP (1982). Engenharia do saneamento ambiental – Rio de aneiro: LTC – Livros Técnicos e Científicos.

Muybi SA, Evison LM (1995). Moringa oleifera *seeds for softening hardwater.* Water Res. 29(12): 1099-1104.

Muybi SA, Evison LM (1995). *Optimizing physical parameters affecting coagulantion of turbid water with Moringa oleifera seeds.* Water Res. 29(12): 2689-2695.

Ndabigengesere A, Narasiah KS, Talbot BG (1995). *Active agents and Mechanism of coagulation of turbid waters using Moringa oleifera*. Water Res. 29(2): 706-710.

CORRÊA MP (1984). Dicionário das Plantas Úteis do Brasil e das Exóticas Cultivadas. Brasília, Ministério da Agricultura, Instituto Brasileiro de Desenvolvimento Florestal. 6v.

Vianna MR (2002). Hidráulica Aplicada às Estações de Tratamento de Água. 4°. Ed. Belo Horizonte Imprimatur.