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Application of *Moringa Oleifera* natural coagulant for clarification and disinfection of treated wastewater in wetlands and multistage filtration

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The use of natural coagulants for water clarification has ecological and environmental importance, being a simple technology to apply in third world regions. This research investigated the effect of natural coagulant obtained from the seeds of *Moringa oleifera* for clarification and disinfection of domestic wastewater treated in wetlands system. The coagulant was used in a multistage filtration unit, which consists by dynamic pre-filter, gravel pre-filter and slow sand filters. The results indicated a removal efficiency of 70.9 and 85.1% for apparent color and turbidity, respectively, and a removal efficiency of 96.1 and 82.8% for total coliform and *Escherichia coli*, respectively, indicating the potential use of Moringa coagulant to aid in wastewater treatment systems.

Key words: Natural coagulant, *Moringa Oleifera*, multistage filtration, wastewater treatment.

INTRODUCTION

Low-cost technologies for water and wastewater treatment are developed to assist small communities without technical staff and with limited financial support. Several technologies may be used, such as multistage filtration, slow sand filtration, solar water disinfection (SODIS) and wetland systems, among others.

The main advantages of these technologies are the minimal use of chemicals and non-specialized staffing for operation and maintenance. However, the low quality of some springs restricts the use of these systems (Sarpong and Richardson, 2010; Vieira et al., 2010). The city of Brusque applies the slow sand filtration technology in regions of Ribeirão Mafra and Volta Grande (Samae, 2012). Moreover, the municipalities of Ituporanga /SC, Corumbataí /SP and Dr. Ulysses /PR also use this technology (Michelin et al., 2011).

The use of coagulants of plant origin to clarify turbid colored water is of great ecological and environmental importance, once the plants contribute to solve ecology problems beautify surroundings and improve the environment, besides producing molecular oxygen, which is an essential component for all living organisms.

Some studies have highlighted the viability of coagulant agents made from polysaccharides, proteins and starches such as cassava flour, arrow root and potato starch, which improve efficiency in reducing suspended solids in water by physical processes (Di Bernardo, 1993).

The natural coagulant extracted from *Moringa oleifera* seeds is relatively easy to obtain and stands out for producing a suspension capable of clarifying turbid waters, being also responsible for controlling waterborne diseases (Sarpong and Richardson, 2010).

Arantes et al. (2009) studied different preparations of *Moringa* seeds in order to obtain an efficient coagulant solution and found that the percentage reduction in

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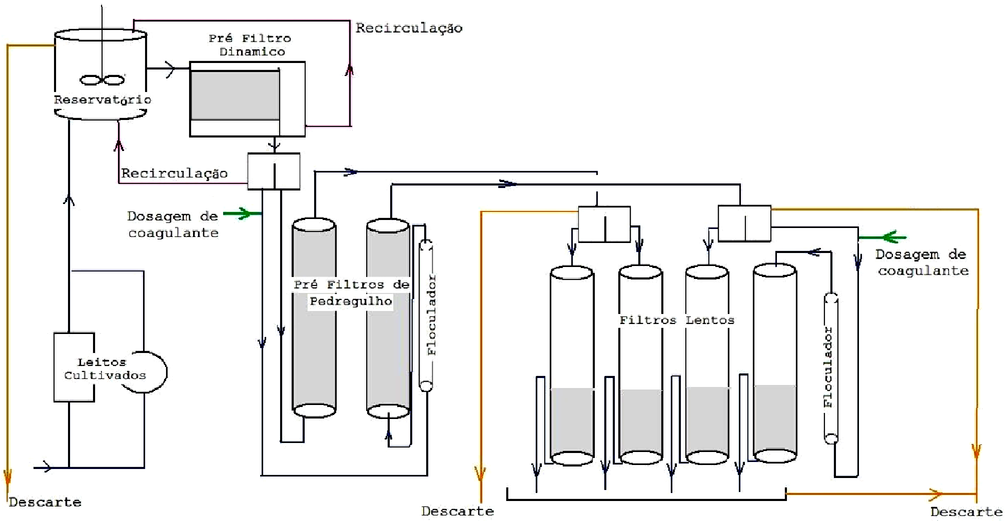

Figure 1. Flow of effluents in wetlands.

turbidity increased from 76.73 to 98% when the solution was used in a slow sand filtration system. Matos et al. (2007) estimated the demand for *Moringa oleifera* seeds and found that it was necessary to provide one seed for each liter of coffee cherry pulping wastewater. The authors described other studies that indicate annual availability is 17,500 seeds per tree, so it is possible to estimate how many trees are needed to produce a certain amount of seed.

This study aimed to evaluate the polishing of treated wastewater in wetlands using the natural coagulant obtained from *M. oleifera* seeds in multistage filtration. The effect of coagulant dosage on clarification and disinfection was evaluated by apparent color and turbidity parameters and total coliforms and *Escherichia coli* enumeration

MATERIALS AND METHODS

Pilot plant

The experiment was conducted in the Laboratory of Hydraulics and Irrigation, Faculty of Agricultural Engineering at UNICAMP (FEAGRI / UNICAMP) in Campinas-SP, whose geographic coordinates are: Latitude 22° 48' 57 " S, longitude 47° 03' 33" W and average elevation 640 m.

Pilot installation

The affluent studied in the present paper was collected from the sewerage system that serves the laboratories of Irrigation and Drainage, Soil, Geo-processing, Thermodynamics and Rural Construction at FEAGRI / UNICAMP, whose effluents are predominantly domestic. For the primary and secondary treatment, two wetlands operating in parallel with equal distribution of the flow were built.

The support layer was composed of gravel and there was no planting or vegetation maintenance in the wetland. Mazzola (2003) concluded that the wetlands did not present significant differences as function of the type of vegetation when the detention times were greater than 24 h. The effluent was then pumped to the multistage filtration system, which was composed by the following units: Reservoir, dynamic pre-filter, upflowing pre-filters and slow sand filters.The dynamic pre-filter was assembled with an area of 0.128 m^2 (0.16 × 0.80 m), consisting of three layers of 0.20 m-thick gravel with a particle size ranging from 19.1 to 25.4, 9.52 to 12.7 and 3.36 to 6.35 mm for the lower, intermediate and surface layer, respectively. The filtration rate was 48 m^3/m^2 a day. The upflowing pre-filters had 0.16 m diameter and 1.60 m height. The filter media consisted of four layers of 0.20 m-thick gravel each, listed in the order of decreasing stream as follows: 12.7 to 19.1, 9.52 to 12.7, 3.36 to 6.35 and 1.68 to 2.4 mm. The filtration rate was 24 m^3/m^2 a day and the *Moringa* coagulant was dosed in only one gravel pre-filter, keeping the other as a control. The slow sand filters were dimensionally identical to the gravel pre-filters, and the filter media consisted of sand with an effective size (D_{10}) 0.25 mm, uniform coefficient (UC) 3 and grain size ranging from 0.08 to 1.00 m with 0.60 m-thickness. Three layers of non-woven fabrics of 400 g/m^2 weight were placed on the top. Only one layer of nonwoven fabric with 150 g/m^2 weight was used for the support. According to Ferraz and Paterniani (2002) and Silva (2006), this design attends the domestic wastewater treatment by slow sand filtration. The filtration rate applied to the slow sand filters was 6 m^3/m^2 a day.

System operation

Figure 1 shows an operating diagram of the multistage filtration system and the points of application of *Moringa* coagulant. Only a portion of the effluent from the dynamic pre-filter was recirculated and mixed to the portion in wetlands in order to maintain a constant flow rate enough to keep the reservoir full. The reservoir had an agitator to prevent sedimentation of solids and maintain the homogeneity of the affluent over time. Both the effluents from the pre-filters and slow sand filters were discarded.

The system worked in continuous operation through a diaphragm dosing pump and the filtration was interrupted after the level of all slow sand filters reached the limit height of 1 m water column. As soon as the filters reached this limit they were drained, cleansed and put back into operation. Discharges were performed in the gravel pre-filter at weekly intervals and no interruption for cleaning

Table 1. Average results of the effluent from the wetlands.

Apparent color [Mg (Pt-Co)L^{-1}]	Turbidity (NTU)	pH	Electrical conductivity (µS/cm)	Total coliforms (MPN/100 ml)	*E. coli* (MPN/100 ml)
272.33	26.12	7.86	682	1.22×10^6	4.24×10^5

Table 2. Efficiency (%) of indicator microorganisms' removal during the assays to define the dosage of coagulant (mean of triplicate determinations, 48 samples).

Dosage of coagulant (mg L^{-1})	Parameter	After filter	After 60 min sedimentation	After 90 min sedimentation	After 120 min sedimentation
250	Total coliform	95.58	91.35	90.13	93.13
	E. coli	96.59	91.23	89.97	95.80
500	Total coliform	0	5.97	41.77	96.77
	E. coli	30.47	43.35	33.48	45.74

was carried out in the dynamic pre-filter during the system operation.

RESULTS AND DISCUSSION

Characterizing effluents from wetlands

The affluent treated in the wetlands was collected from the sewerage system of the Laboratories of Sanitation, Irrigation and Drainage, Geo Processing and Soils at FEAGRI / UNICAMP, whose affluent is predominantly domestic.

Table 1 shows the mean of triplicate determinations of the characteristics of the effluent from the wetlands in the multistage filtration system. The results are similar to those obtained by Londe (2002) and Silva (2006), who also used wetlands to treat domestic sewerage.

Determining the dosage of *Moringa* coagulant

Assays were performed to define the dosage of coagulant necessary to provide better removal of coliform bacteria and to evaluate the bactericidal effect of the *Moringa* solution in the jar-test. These experiments were performed with a 40 s^{-1} velocity gradient to avoid sedimentation.

The *Moringa* solution was put into the jars containing the effluent from the wetlands and samples were collected after 30, 60 and 120 min (RAMOS, 2005)

Three different dosages were studied: 0 (control), 37 mg L^{-1} at 0.67% w/w; 250 mg L^{-1} at 2.0% w/w, and 500 mg L^{-1} at 2.0% w/w. These values were taken from the literature as described by Ramos (2005). The initial sample was called *Gross Sample*.

For the coagulant dosage of 37 mg L^{-1} at 0.67% w/w the results have shown no efficiency in total coliforms and *E. coli* inactivation, once the control sample presented better results, thus this dosage was not studied.

The dosages 250 and 500 mg L^{-1} at 2.0% w/w presented similar results, which were 52 and 59% efficiency of total coliforms inactivation, respectively. In addition, for *E. coli* inactivation the efficiency was 61 and 69% at 120 min sedimentation time. Then, replication were performed at 60, 90 and 120 min only for the dosages 250 mg.L^{-1} at 2.0% w/w and 500 mg L^{-1} at 2.0% w/w by using the clotted effluent in non-woven synthetic fabrics without sedimentation time. In this second step, better efficiencies were obtained for dosages of 250 mg L^{-1} and reduced efficiency for the dosages of 500 mg L^{-1}, as shown in Table 2. Based on these results, we used the dosage of 250 mg L^{-1} in the multistage filtration system, since the results suggested greater efficiency of microorganisms' removal.

Literature shows wide variation of the coagulant dosage used in water samples, as follows: 36 mg L^{-1} in lake water (Ramos, 2005), 75 mg L^{-1} in river water (Pritchard et al., 2010) and 12,000 mg L^{-1} in pond water (Amagloh and Benang, 2009). These values may be due to the different characteristics of the water to be studied, as well as the effects of salinity, temperature and pH.

Testing multistage filtration system with the dosage 250 mg L^{-1} of coagulant

The assay was performed during 45 days, once at this time all the filters presented the maximum water depth of 1 m. The slow sand filtration unit using *Moringa* coagulant reached the water depth of 1 m after 35 days. However, the filtration process was not interrupted until 45 days, when filtration finished in all the slow filtration systems. The effluent turbidity of the filtering system, so called inlet, showed values of 15.47 NTU and the apparent color presented a mean value of 124.1 mg (Pt-Co) L^{-1} as shown in Table 3. Statistical analysis by ANOVA showed

Table 3. Mean values (16 samples) of apparent color and turbidity.

Parameter	Inlet	Dynamic pre-filter	Pre filter without coagulant	Pre filter with coagulant	Slow sand filter before clotting	Slow sand filter without coagulant	Slow sand filter with coagulant
Turbidity (NTU)	15.47	7.45	5.81	2.25	2.29	3.17	2.30
Apparent color mg(Pt-Co)/L	124.1	84.1	64.9	58.8	39.1	44.6	36.1

Table 4. Total coliforms and *E. coli* (MPN/100ml) enumeration (16 samples).

Variable		Inlet	Treatment without coagulant	With addition of coagulant in pre-filter	With addition of coagulant in slow sand filter
	Mean	1.22×10^6	2.36×10^5	7.66×10^5	1.76×10^5
Total coliforms	Ma×Imum	2.48×10^6	4.84×10^5	2.42×10^6	2.42×10^5
	Minimum	3.69×10^4	1.01×10^5	1.99×10^5	1.30×10^4
Efficiency (%)	Mean	-	76.9	25.0	82.8
	Mean	4.24×10^5	2.76×10^4	1.53×10^4	2.57×10^3
E. coli	Ma×Imum	1.10×10^6	6.24×10^4	4.50×10^4	5.48×10^4
	Minimum	9.80×10^3	9.78×10^3	2.00×10^2	1.79×10^2
Efficiency (%)	Mean	-	93.5	96.4	99.4

differences between the samples from the inlet and outlet sections (p = 0.05). According to Ramos (2005), the better efficiency of the *Moringa* coagulant was observed in high turbid water. In the present study, despite the turbidity of the affluent is relatively low, the system had an organic matter. Thus, both gravel pre-filter and slow sand filter presented the lowest turbidity values when the coagulant was used.

In the gravel pre-filter units, the best efficiencies for both color and turbidity parameters occurred in the units with addition of coagulant. A better efficiency was also observed in the slow sand filters where the coagulant was added either directly at the unit or to the pre-filter. The parameters pH, temperature, dissolved oxygen and electrical conductivity were also monitored throughout the experiments and the results showed no changes in the filtration units.

Table 4 shows the results of total coliforms and *E. coli* inactivation regarding the enumeration of total coliforms as function of the coagulant dosage, all systems showed an improvement in reduction of this microrganism; the pre-filter unit presented lower removal efficiency (25.0%) while the slow sand filtration presented the best removal efficiency (82.8 %). In respect to the samples without addition of coagulant, the efficiency was 76.9%. This result is similar to that obtained by Sarpong and Richardson (2010), who found removal efficiency of 77% for total coliforms only by using the *Moringa* coagulant and sedimentation in jar test.

Amagloh and Benang (2009) obtained 99% removal of total coliforms and 17 MPN (100 ml $^{-1}$) *E. coli* in stabilization pond effluents using *Moringa* seeds solution at 12 g L^{-1}. A higher removal efficiency of *E. coli* was also observed when the coagulant was used in the slow sand filter (99.4%). Similar results were found by Pritchard et al. (2009), who obtained a removal efficiency of 98% when the initial enumeration of *E. coli* was 10^4 MPN (100 ml^{-1}).By applying the coagulant in the pre-filter, the removal efficiency of *E. coli* was 96.4%, being more efficient than the pre-filter without addition of *M. oleifera* coagulant, which showed 93.5% efficiency.

The statistical analysis by ANOVA showed significant differences in total coliforms (p = 0.05) and *E. coli* (p = 0.01) counts between the inlet and outlet sections. Comparing the treatments, the difference was significant at p = 0.20 for both parameters.

Conclusions

The results in Tables 3 and 4 showed that the removal efficiency for total coliforms and *E. coli* was of one log cicle (90% efficiency). The use of *Moringa* coagulant increased the removal efficiency for effluents with total coliforms level of 1.22×10^6 MPN (100 ml^{-1}) and *E. coli* level of 4.24×10^5 MPN (100 ml^{-1}). The best removal efficiency for *E. coli* was obtained in the slow sand filter, with values of 99.4% removal efficiency, corresponding to 2.57×10^3 MPN (100 ml^{-1}). The present study indicated that *M. oleifera* seeds have a potential on removing total coliforms and *E. coli* when the coagulant solution is used for treating wastewater in wetlands and multistage filtration. Analysis of variance showed reliability of 20% between the treatments studied, so the continuity of the study may improve these results.

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