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Coagulation diagram using the *Moringa oleifera* Lam and the aluminium sulphate, aiming the removal of color and turbidity of water

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ABSTRACT. This work suggests the study of the coagulation diagram as a tool to verify the efficiency in removing color and turbidity of the water, using the *Moringa oleifera* Lam and the association of this biopolymer with the aluminium sulphate as coagulating agents. The assays were carried out in Jar Test, by varying the concentrations of coagulants and pH of coagulation. After the assays of coagulation/flocculation/sedimentation, samples were collected for the evaluation of the process efficiency. Best results were obtained at dose of 50 ppm of *Moringa oleifera* Lam. When associating the coagulants, the addition of the aluminium sulphate provided an increase in the efficiency of coagulation/flocculation, whose parameters of control used were color and turbidity. It was verified that the study of the coagulation diagram is useful, since it enables developing the assays in the optimal range, as a function of the raw water characteristics. The use of the *Moringa oleifera* Lam can be considered as an alternative technique to the conventional treatment.

Keywords: water treatment, biopolymer, chemical coagulant, quality parameters.

Diagramas de coagulação utilizando a *Moringa oleifera* Lam e o sulfato de alumínio, visando a remoção de cor e turbidez da água

RESUMO. Este trabalho propõe o estudo dos diagramas de coagulação como ferramenta para verificar a eficiência de remoção de cor e turbidez da água bruta, utilizando como coagulante a *Moringa oleifera* Lam e a associação deste biopolímero com o sulfato de alumínio. Os ensaios foram realizados em *Jar Test*, variando-se as concentrações dos coagulantes e o pH de coagulação. Após os ensaios de coagulação/floculação/sedimentação, foram coletadas amostras para a avaliação da eficiência do processo. Os melhores resultados obtidos para os parâmetros avaliados corresponderam a uma dosagem de solução padrão de *Moringa oleifera* Lam equivalente a 50 ppm. Quando da associação dos coagulantes, a adição do sulfato de alumínio proporcionou um aumento na eficiência da coagulação/floculação, cujos parâmetros de controle utilizados foram cor e turbidez. Verificou-se que o estudo do diagrama de coagulação é útil, pois possibilita o desenvolvimento dos ensaios nas regiões ótimas, em função das características da água bruta. A utilização da *Moringa oleifera* Lam pode ser considerada como uma técnica alternativa ao tratamento convencional.

Palavras-chave: tratamento de água, biopolímero, coagulante químico, parâmetros de qualidade.

Introduction

Water is an essential element of life, and shall comply with the standards of potability in order to supply the world's population. However, small communities, rural areas and suburbs, often lack suitable sources of water, and it is important to have alternative techniques of attempting to solve this problem.

Raw water contains many impurities in the form of suspended and dissolved solids, which do not approach each other, if their characteristics are not altered by the addition of coagulants.

Aluminium sulphate is widely used as chemical coagulant in the world, but recently its use has been discussed owing that there are studies have verified that the relation of aluminium sulphate with the acceleration of the degenerative process of Alzheimer's disease (CLAYTON, 1989). In addition, aluminium is not biodegradable and can cause problems of disposal and treatment of sludge generated.

The natural coagulants/flocculants have shown advantages over chemicals, particularly in relation to biodegradability, low toxicity and low production of waste sludge (KAWAMURA, 1991). Thus, in various countries many plants are being used as coagulants/flocculants, where some have been investigated more intensively, such as *Moringa oleifera* Lam.

The *Moringa oleifera* Lam (Figure 1) belongs to the *Moringaceae* family, which is composed of only one gender (*Moringa*) and 14 species. It is a small tree, native of northern India, has rapid growth, which adapts to a wide range of soil and is drought tolerant (McCONHACHIE et al., 1999).

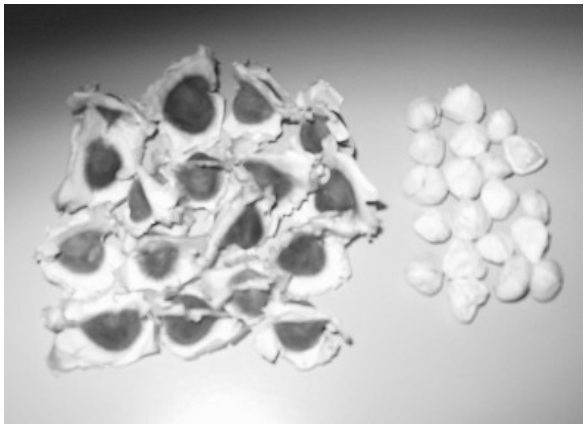

Figure 1. *Moringa oleifera* Lam seeds with and without bark.
Source: Author

According to Ndabigengesere and Narasiah (1996), the seed of *Moringa oleifera* Lam is a viable alternative coagulant to replace aluminium salts. Compared with aluminium, these seeds did not significantly alter the pH and alkalinity of the water after treatment and do not cause corrosion problems.

Moreover, the process efficiency using *Moringa oleifera* Lam does not depend on the pH of the raw water (SCHWARZ, 2000), unlike the aluminium sulphate, which has restricted application to pH between 5.5 and 8.0.

The pulp from *Moringa oleifera* Lam seeds acts as a clarifying agent for water by the presence of a cationic protein of high molecular weight, which destabilizes the particles contained in the water and flocculate colloids (NDABIGENGESERE et al., 1995).

The mechanism of coagulation/flocculation by the protein contained in the *Moringa oleifera* Lam pulp similar to that verified when using polyelectrolytes (DAVINO, 1976).

When the coagulation/flocculation is carried out by addition of polyelectrolyte there are no neutralization reaction between the coagulant and water impurities, suspended and dissolved solids. The polyelectrolytes are constituted of complex with large molecular chains, that have sites with positive or negative charges, with high adsorption capacity of particles around it.

Popinigis (1985) and Bezerra et al. (2004), believes that the storage of *Moringa oleifera* Lam seeds reduces the physiological quality by degenerative changes features of decay. Thus, it is ideal to use fresh seeds for water treatment in order to prevent degradation of the coagulant protein.

Until now, no evidence was found that these seeds can cause some side effects in humans, especially with the doses required to water treatment (SCHWARZ, 2000). Thus, it can be stated that treatment with *Moringa oleifera* Lam seeds does not have health risks.

As the coagulation widely employed in water treatment, a tool that is able to predict which is the most effective pH for coagulation occurs and the coagulant dosage required, it is extremely useful (CAMPOS et al., 2005; KIM et al., 2001).

Thus, this study aims to the use of diagrams as a tool to check removal efficiency of turbidity and color parameters, using *Moringa oleifera* Lam as coagulant, and the association of this polymer with the chemical coagulant aluminium sulphate, in addition to checking the best coagulant dosage as a function of pH, for water with color and turbidity relatively low.

Material and methods

The raw water used was collected from the Sanitation Company of Paraná - Sanepar, from the Pirapó river basin. For these trials were considered waters having low color/turbidity, under the conditions studied. It is worth mentioning that the collection was held in the dry season.

Coagulation/flocculation tests were carried out in 'Jar Test', using six beckers containing 200 mL of raw water, where in each of these were added predetermined amounts of the solution. The speeds were set at 95 rpm for 3 min. and 10 rpm for 15 min., to provide rapid and slow mixing, respectively. Afterwards, the beckers were at rest for 120 min.

It was used the raw water collected on different days, when the use of *Moringa oleifera* Lam natural coagulant, and the association of *Moringa oleifer*a Lam and aluminium sulphate coagulants.

The water temperature was maintained in the range of $25.0 \pm 3.0^{o}C$ for the tests.

For the preparation of *Moringa oleifera* Lam standard solution, it was considered a concentration of 1% w v^{-1}, ie, for each 1 g of *Moringa oleifera* Lam seed pulp, were added to 100 mL of distilled water. This was crushed in a blender and filtered under vacuum.

The *Moringa oleifera* Lam solution was prepared at the time of conducting the test, because studies have shown that the storage solution for a few days can cause inefficiency of the process, over a deterioration process of the solution by microorganisms (MUYIBI; EVISON, 1995).

For the construction of the coagulation diagrams when the use of *Moringa oleifera* Lam coagulant, the dosage of solution used are specified in Table 1.

Table 1. Dosages of *Moringa oleifera* Lam solution.

Dosages (ppm)	50	100	150	200	250	300	350	400	450	500	550	600

For the preparation of the standard solution of aluminium sulphate, it was dissolved 10,309 g of aluminium sulphate of 97% of purity in distilled water and the volume was completed for 1 L, to obtain a standard solution with concentration of 1%.

For the association of the studied coagulants, the concentrations variations of aluminium sulphate/*Moringa oleifera* Lam were carried out in the following way: 55/0 (1), 50/50 (2), 45/100 (3), 40/150 (4), 35/200 (5), 30/250 (6), 25/300 (7), 20/350 (8), 15/400 (9), 10/450 (10), 5/500 (11), 0/550 (12) ppm of aluminium sulphate/ppm of *Moringa oleifera* Lam.

The values of pH coagulation used were ajusted for 4.0, 5.0, 6.0, 7.0 and 8.0, with sodium hydroxide (NaOH) 25 and 50% and sulfuric acid P.A solutions. The measurements were carried out using a pH-meter Digimed.

After the end of the coagulation/flocculation/ sedimentation stages, a sample was collected of approximately 30 mL of each beckers at approximately 2 cm of the surface.

The parameters apparent color and turbidity were assessed by analysis accomplished in spectrophotometric HACH DR/2010, according to the procedure recommended by the Standard Methods (APHA, 1995).

The coagulation diagrams were built from the obtained data. The program used for the construction of the coagulation diagrams was the 3DField 2.7.0.0.

This diagram consists to plot all the values of parameters removal like color and turbidity obtained in the performed tests, varying the pH coagulation and the coagulant dosage and then, to obtain ranges where those removal percentages are considerable, for finally to choose the study points.

Results and discussion

The waters characteristics used for the construction of the coagulation diagrams using the coagulants *Moringa oleifera* Lam and association of coagulants are shown in the Table 2.

The coagulation diagrams show the pH coagulation in the abscissas axis and the coagulant concentration in the ordinates axis.

Table 2. Characteristics of raw water used for the tests in 'Jar Test'.

Parameter	Unit	Values (*Moringa oleifera* Lam)	Values (*Moringa oleifera* Lam e Aluminium Sulphate)
Apparent Color	uH[1]	302	150
Turbidity	uT	73	24
TDS[2]	mg L^{-1}	116	168
TOC[3]	mg C L^{-1}	3.4	1.7

[1]Hanzen unit = (mg Pt-Co.L^{-1}). [2]Total Dissolved Solids. [3]Total Organic Carbon.

In the Figures 2 and 3 are shown the coagulation diagrams for the biopolymer *Moringa oleifera* Lam, in function of the efficiency of color and turbidity removal, respectively.

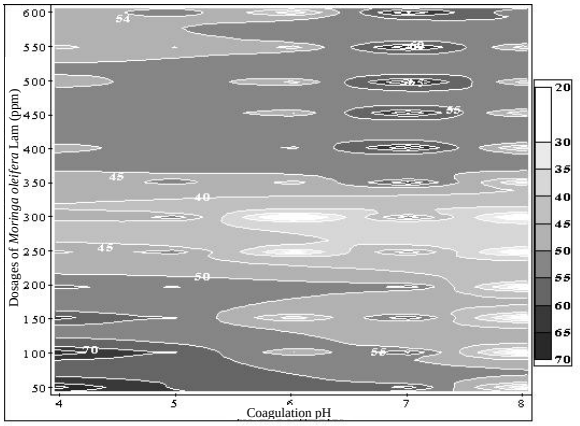

Figure 2. Coagulation diagram using *Moringa oleifera* Lam containing color removal curves.

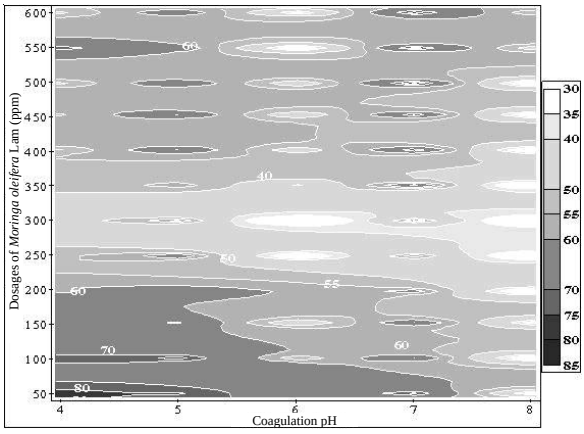

Figure 3. Coagulation diagram using *Moringa oleifera* Lam containing turbidity removal curves.

The best results found for the assessed parameters corresponded to a standard solution dosage of *Moringa oleifera* Lam equivalent to 50 ppm, what was expected, because the coagulant dosage to be used depends on the initial turbidity of the water.

According to Bawa et al. (2001), the treatment for waters that present low turbidity is difficult, because the formed flakes present low settleability. In other words, the *Moringa oleifera* Lam seeds are

less effective in waters of low turbidity, when it comes to the studied parameters reducing.

From the obtained results, it can be observed that intermediate removals, above 50%, for the two quality parameters in subject were obtained from the *Moringa oleifera* Lam standard solution dosage of 400 ppm.

However, it was verified in the coagulation diagrams for waters of low color/turbidity that the obtained results are not of removals relatively high for color and turbidity.

It is noteworthy that, besides acting in an extensive pH range, the seeds of *Moringa oleifera* Lam didn't alter the pH of the water significantly after the treatment performed.

In the Figures 4 and 5 are shown the coagulation diagrams, for the natural coagulant *Moringa oleifera* Lam with the chemical coagulant aluminium sulphate, in function of the efficiency of color and turbidity removal, respectively.

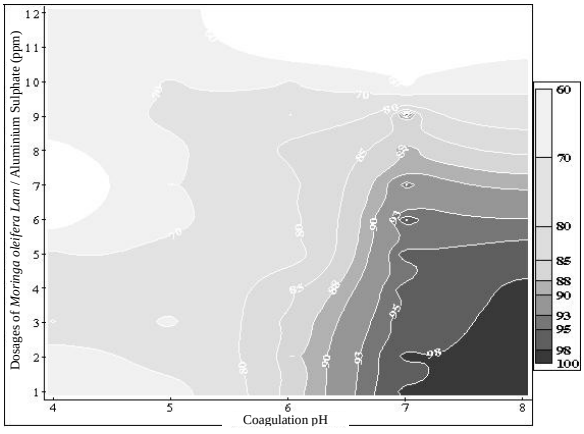

Figure 4. Coagulation diagram using *Moringa oleifera* Lam and Aluminium Sulphate containing color removal curves.

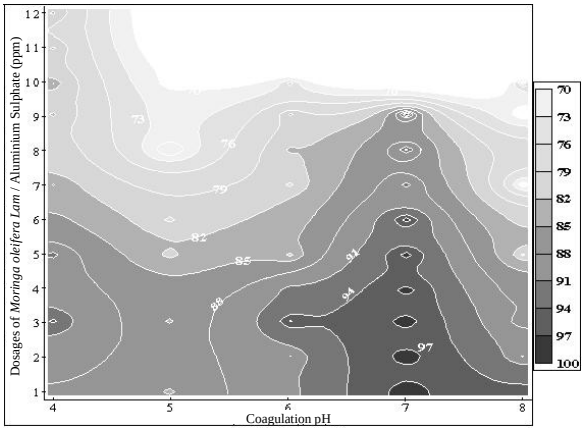

Figure 5. Coagulation diagram using *Moringa oleifera* Lam and Aluminium Sulphate containing turbidity removal curves.

Color removals above 85% were obtained for the pH coagulation between 6.5 and 8.0, until the point 9 (Figure 4). In pH smaller than 5.5, it is observed removals below 80%, proving that the aluminium sulphate acts better in pH larger than 5.5.

Comparing the coagulation diagrams for the parameter color in waters of low color/turbidity (Figures 2 and 4), it is observed clearly that, the addition of the aluminium sulphate, even in small amount, provided an increase in the parameter removal.

High turbidity removals, above 90% were obtained in some points, however, with a high dosage of chemical coagulant for raw water of low color/turbidity.

It is noticed that the coagulation diagrams built for the two parameters, when using the coagulants association (Figures 4 and 5), presented better removals than the diagrams built using *Moringa oleifera* Lam standard solution (Figures 2 and 3).

It is noteworthy that, considering the purpose of drinking water production, the filtration is recommended after the coagulation/flocculation/ sedimentation stage, in order to get with that the quality parameters fit in the maximum values allowed by the legislation (BRASIL, 2004).

Also it is important to perform the water disinfection through the chlorination, order to ensure the absence of total coliforms.

From the coagulation diagrams obtained, it can be defined the optimized areas of color and turbidity removal, considering the quality of raw water used, according to the studied experimental conditions.

Conclusion

From the coagulation diagrams when using *Moringa oleifera* Lam, it was observed that good removal efficiencies were obtained using the solution of 50 ppm from standard solution added to the coagulation/flocculation/sedimentation process.

It was also noticed that, the addition of aluminium sulphate, even in small amount, it provided an increase in the removal of the appraised parameters.

It can be verified that the use of the coagulation diagram as a tool for the determination of the work conditions in the coagulation/flocculation/ sedimentation processes is valuable, because it makes possible the indication of great process conditions, in function of the characteristics of the raw water.

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