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Water Treatment with Conventional and Alternative Coagulants

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Half of the world's population does not have access to basic sanitation, leading to socio-economic problems, such as the lack of drinking water and the spread of diseases. In this way, the development of water treatment technologies that are accessible to that target people is of utmost relevance. Currently, in the water treatment of separation process, the compound mostly used as a coagulant in water treatment is the aluminum sulphate, which gives good results for turbidity and color removal of raw water. However, studies show that its deposition in the human body can cause serious damage to health, and the development of diseases, including Alzheimer's disease. Thus, this project set out to do a parallel study between the aluminum sulphate coagulant and as an alternative, the seed extract of Moringa oleífera (MO). The efficiency of both coagulants were evaluated through measurement of turbidity and color of water samples. MO proved to be more efficient, with removals of 94.9% of turbidity and 92.5% of color, when using a dosage of 20 mg L^{-1}. The water obtained results close to drinking water required by Brazilian regulation, indicating that MO seed could be an alternative for water treatment providing water for small communities.

1. Introduction

Water treatment is still a challenge and a source of problems, such as health-hazardous chemical coagulants and dissolved organic carbon, that require solution in many communities. Water quality is mandatory to achieve consumption standards. The most frequently used inorganic/synthetic coagulants used in coagulation/flocculation processes around the world are aluminum polychloride and aluminum sulfate (Baptista et al., 2015). High residual concentration may still be remaining at the end of the treatment which is a rather important concern for public health authorities. In fact, an increanse in the demand for alternative coagulants of natural origin, which are efficient, cost effective, readily available and non-toxic (Tukki et al., 2016, Lo Monaco et al., 2010).

In recent years several studies have been developed towards the use of natural coagulants alternatives to replace chemical coagulants to obtain potable water. Initial studies were concerned to assist or replace conventional coagulants in order to improve the stage of coagulation/flocculation, related to the quantity of flakes, and also related to the absence of metal sludge produced. Consequently, a concern for the health of the population, especially in relation to Alzheimer's disease, according to studies, can be aggravated by aluminium (Flaten et al. 2001).

The use of materials of natural origin for clarification of surface water with high turbidity concept is not new.

MO is a plant whose seeds contain a protein that can be used as a natural organic coagulant to treat water and wastewater. In comparison with conventional inorganic coagulants, MO presents several advantages, such as inexpensive, non-corrosive, non-toxic to the environment, biodegradable, lower cost, has good color and turbidity removal and also promotes removal of bacteria (Dasgupta et al., 2016; Dalvand et al., 2016).

Previous studies have shown that MO extracts are quite efficient as a natural coagulant in reducing colour, turbidity and microorganisms from raw water (Carvalho et al., 2016; Camacho et al., 2013; Madrona et al.,

2010). Besides, the cost of this natural coagulant would be less when compared to the conventional coagulant in water purification since it is available in most developing countries rural communities where treated water is a scarce resource (Ghebremichael, 2004).
Thus, this reaseach proposed to do a parallel study between two coagulants: the chemical conventional coagulant, aluminum sulphate and the natural alternative coagulant, MO seed extract. The dosages were optimized for both coagulants and the efficiency was evaluated through measurement of turbidity and color. The results were analyzed and the best alternative was determined.

2. Materials and Methods

For this work, water was taken from Borba Gato Small River, located in Maringá City, PR. Samples were kept and stored in containers, inside a freezer, during the entire experiment. In the laboratory were used the following equipments: Jar Test Nova Ética 218 LDB - six jars, used in bench-scale simulating processes of coagulation and flocculation for water. Buchnner- funnel , used for filtering, after coagulation, flocculation and settling stages. pHmeter - Thermo® Scientific Orion Versa Star. Spectrophotometer (Hach DR/2010) for measures of colour and Turbidity. The first procedure was to analyze some parameters of the raw water collected, such as color, turbidity and pH.

2.1 *Moringa oleifera* seeds

The seeds were peeled, crushed and transformed into powder. Then, 1 gram of the powder was diluted at 100 mL of distilled water, shaken for 30 minutes, and it was vacuum filtered. Preliminary tests were made seeking for the best concentration range for working with MO. The next step, after the determination of the best range (that was from 10 to 30 ppm) to develop this work, the stock solution was diluted in the following concentrations: 10,15, 20, 25 and 30 mg L^{-1}.

2.2 Aluminium sulphate (Al_2SO_4)

For making a stock solution, It was weighted 1 gram of aluminum sulphate and it was diluted to 500 mL of distilled water. From the stock solutions, it was made some solutions, concentrations at 10,15, 20, 25 and 30 mg L^{-1}.

2.3 Coagulation/flocculation/sedimentation experiments

After the preparation of MO and aluminium sulphate solutions, samples were mixed in Jar test, after the addition of coagulant solution. The experimental conditions were: rapid mixing gradient of 100 rpm for 3 min; after, slow mixing gradient of 40 rpm for 20 min. The settling time was of 60 minutes. This procedure was made for each dosage/ test. For each sample it was measured the parameters, as turbidity, color and pH.

3. Results and Discussion

Noting a visible color present in the solution of MO, the first procedure was to analyze the same at the physical and chemical parameters for the solution of MO. In this study the color present at MO was approximately 14 times the color of the raw water; the turbidity was the double. These data can take researchers to give up working with MO. Then this work decided to characterize not only the raw water, but also the MO and aluminum suphate, showed at Table 1.

Table1: Parameters of characterization of raw water, MO and aluminium sulphate solutions

Parameters	Raw water	*Moringa Oleifera* (MO) solution	Aluminium Sulphate solution
Turbidity (NTU)	157	315	1
Color (U.H)	360	4950	2
pH	8.14	6.55	4.23

The color derives from the fact that the seed be a natural element, being composed by an oilseed crop proteins, lipids and acids transoleic isomers; l these compounds given to MO the intrinsic characteristic of high color and turbidity.

3.1 Use of *Moringa oleifera*

3.1.1. Color removal

Using the solution of MO, the sample with 20 mg L^{-1} have obtained the best results in terms of color removal, besides, the amount of sludge was reduced, when compared with the aluminum. Beyond, the sludge

generated has biodegradable characteristics, which makes its use ideal in composting, unlike the sludge generated by aluminum sulphate that has characteristics requiring an appropriate inorganic treatment for its final destination.
The results of the color parameter of the treated water samples with the MO are set out at Figure 1 that shows the color removal of samples.

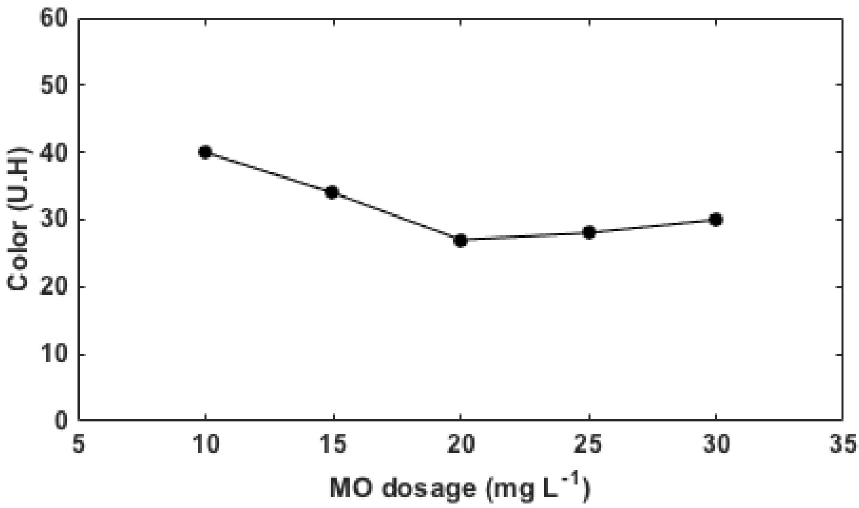

Figure 1: Color removal with MO.

It is observed at Figure 1 that the removal of color is improved with a small increment of its concentration, just getting the MO best concentration required. The sample with 20 mg L^{-1} presented the lower value (27 U.H) of color which means it presented the biggest color removal (92.5%). All samples presented equal performance (88.9-92.5%), indicating that all dosages are efficient. Dosages higher than 20 mg L^{-1} loses efficiency, showing that the 20 mg L^{-1} is the optimum value to be followed at water treatments stations.

3.1.2 Turbidity removal

The dosage of 20 mg L^{-1} also obtained the best results in terms of turbidity removal. The results of turbidity removal using MO are shown in Figure 2.

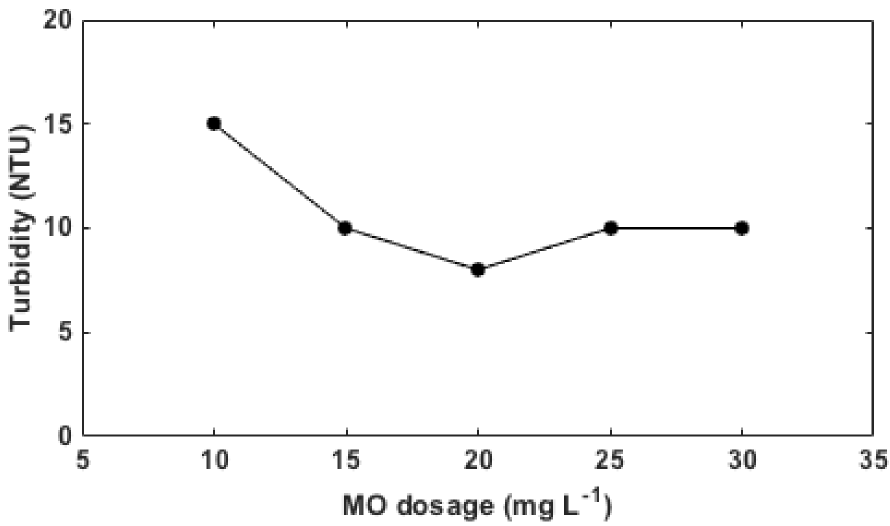

Figure 2: Turbidity removal with MO.

The result for MO dosage of 20 mg L^{-1} presented the lower value of turbidity (8 NTU), it presented the higher turbidity removal (94.9%). It means that the best MO concentration is 20 mg L^{-1} of MO for color and turbidity removal.

It is noticed that as it is increased the amount of MO dosase it is also increased the removal of turbidity and color, but just until a certain limit. Analyzing the data obtained in this work, it is seen that the dosage of 20 mg L^{-1} of MO presented the best removal of color and turbidity. Others studies lead to evaluate the MO coagulant, obtaining a optimum removal point, and with higher dosages its efficiency decays. According to Ghebremichael et al. (2005), this happens because the MO extract have high concentration of organic matter, nutrients and vitamins. These characteristics can interfere directly with the coagulation/flocculation process making initially an increase at the values of organic matter, color and turbidity. And according to Carvalho et al. (2016) MO seed consists of a large amount of protein, and the active portion of this coagulant is linked precisely to the presence of a positively charged cationic protein with high molecular weight, which destabilizes particles that are present in water and promote the coagulation of colloids.

3.1.3 pH

The results for pH mesurements it was not observed an accentuated difference among studied samples. All of samples remained in the range of pH within the specifications of Portaria 2914 (Brasil, 2011), which range between 6.0 and 9.5. The results are shown in Figure 3.

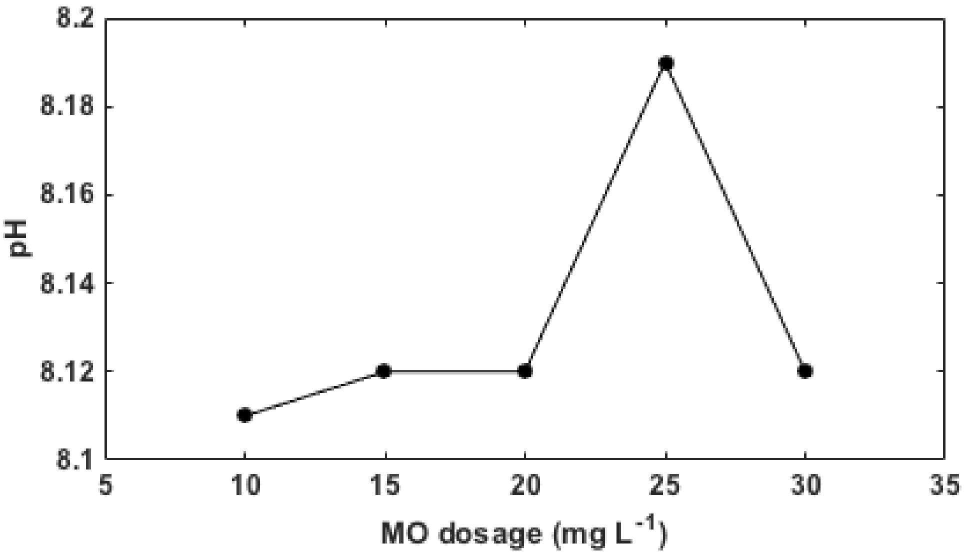

Figure 3: pH values with MO.

3.2 Use of Aluminium Sulphate

The use of aluminum sulphate as a coagulant with a gradual increase of concentrations showed a proportional increase in turbidity and color removal of the treated samples. The results are shown in Table 2. The values of raw water are also shown for comparison.

Table 2: Water parameters analyzed after the use of Aluminum sulphate

Parameters	Raw water	10 ppm	15 ppm	20 ppm	25 ppm	30 ppm
Turbidity (NTU)	157	99	66	27	22	21
Color (U.H)	360	300	296	276	176	163
pH	8.140	7.51	7.77	7.79	7.77	7.77

It is seen that the optimum point is not obtained, it is necessary to increment the concentration of this salt to obtain an appropriate removal. This means that it is necessary to continue increasing the aluminium sulphate dosage to obtain better results. It might become a problem because by increasing the aluminium sulphate concentration, also increase the aluminium residual in the treated water and that can cause health problems.

This situation is contrary when compared to the use of MO, which has an optimum value, and when using a dosage above it, the results get gradually worse.

In relation to the pH, the values are exposed in Figure 4, and it is possible to see that there is a slight pH variation, when applied to the different dosage of salt coagulant.

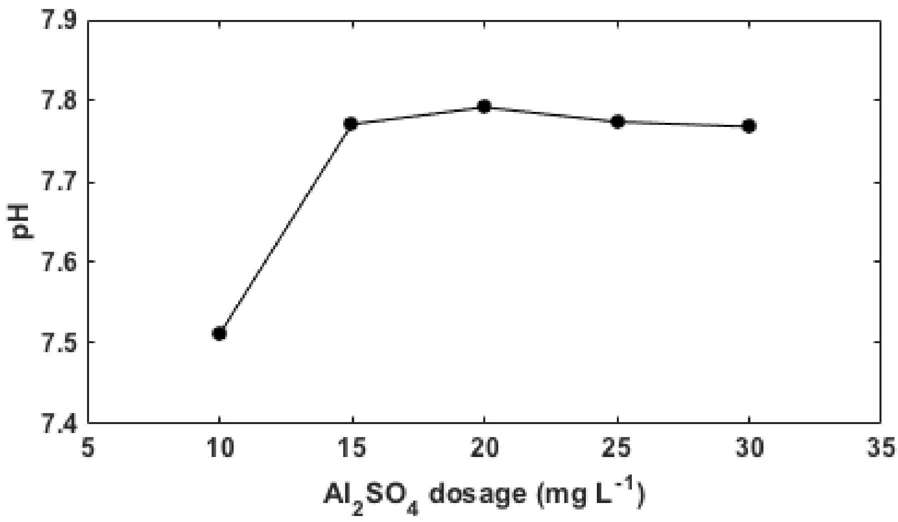

Figure 4: pH values using aluminium sulphate

It is important to notice that the results presented in Figure 4 showed lower pH values when compared to the raw water, since the use of aluminium sulphate as coagulant acidifies the aqueous media.

3.2.1. Comparison of coagulants results

Table 3 shows the results of the two treatments for all five concentration used in this study. The natural MO and the chemical aluminum sulphate.

Table 3: Water parameters analyzed after the use of the MO and the Aluminum sulphate.

Parameters	10 ppm		15 ppm		20 ppm		25 ppm		30 ppm	
	MO	Al_2SO_4	MO	Al_2SO_4	MO	Al_2SO_4	MO	Al_2SO_4	MO	Al_2SO_4
Turbidity (NTU)	15	99	10	66	8	27	10	22	10	21
Color (U.H)	40	300	34	296	27	276	28	176	30	163
pH	8.11	7.51	8.12	7.77	8.12	7.79	8.19	7.77	8.12	7.77

All the results with the natural coagulant presented best results when compared with the chemical coagulant. For all dosages studied, MO 20 mg L^{-1} presented the best results. This result can be considered to be used for water treatment stations.

Conclusions

MO natural coagulant presented best results of color and turbidity removal when compared with aluminum sulphate chemical coagulant for all samples analyzed. Although this work showed that there is an inherent MO solution color, it showed high turbidity removal (94.9%) and color removal (92.5%) with the best dosage of 20 mg L^{-1}.In this way, this work has shown the efficiency of natural coagulant MO for removing color and turbidity of water, obtaining values very close to drinking water. MO seed could be an accessible tool for providing water for human consumption at small communities, which can easily get this plant and harvests its seeds. In addition to be natural, this plant is biodegradable and does not provide any kind of threat to the human organism.

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