Raissa Rachel Salustriano da Silva-Matos
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(Organizadores)

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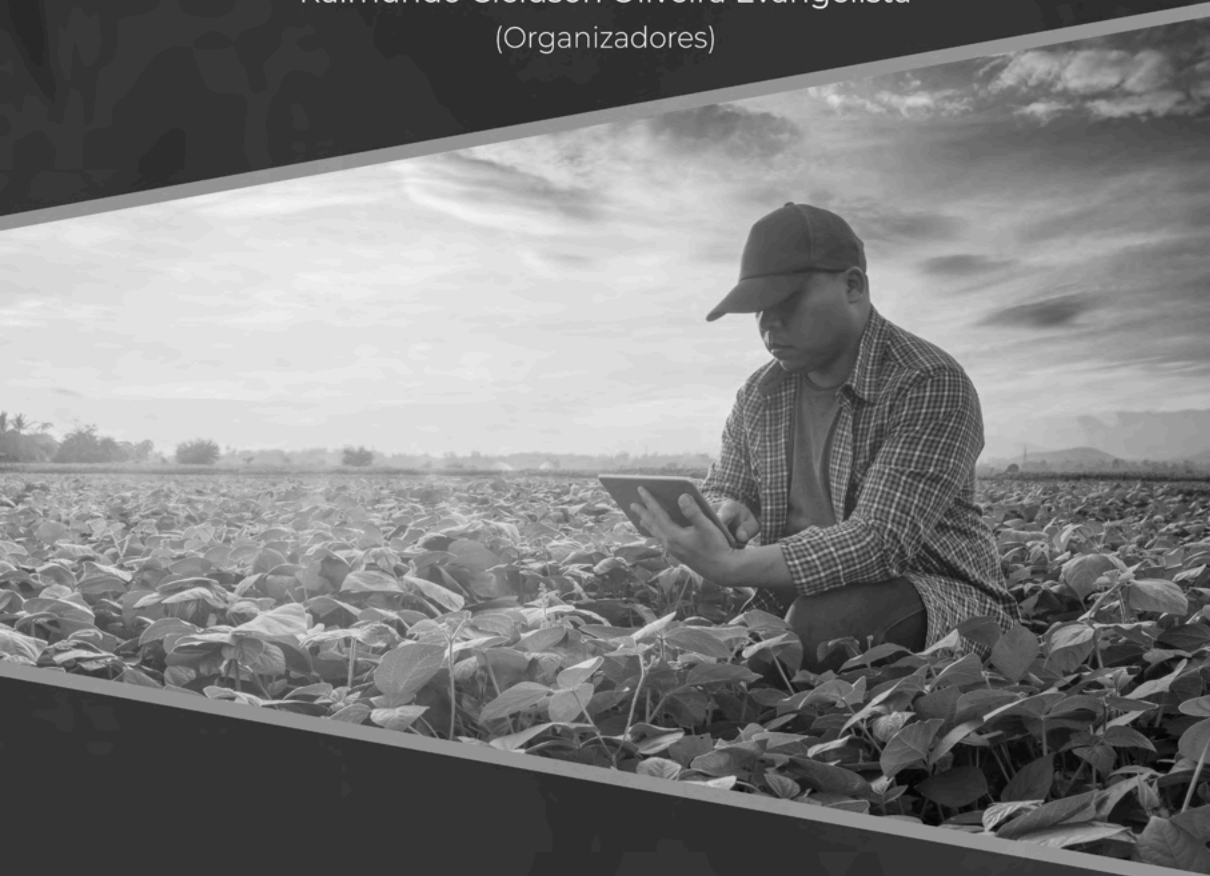

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APRESENTAÇÃO

O processo que decorre sobre a investigação científica ocorre concomitantemente a necessidade de solucionar problemas e encontrar respostas para métodos que necessitam ser validados junto a fenômenos que requerem explicações assertivas e com bases sólidas. Desta forma, a importância do método científico está assegurada à uma constante carência de respostas e confirmações não sustentadas apenas pelo empirismo.

Existe uma grande necessidade de soluções que possam solucionar a demanda por alimentos, criada com o crescente aumento populacional. Uma das principais preocupações para os próximos anos será aumentar a produtividade sem aumentar o espaço produzido, tornando a agricultura mais sustentável e isto será fruto de investigações científicas, por exemplo.

Por isso, é inevitável notar que grandes são os desafios para tornar a agricultura mais pujante e eficaz, respeitando o meio ambiente e conseguindo suprir as demandas da sociedade. Para isso, há muito tempo pesquisas vêm sendo desenvolvidas com o objetivo de colaborar para o aprimoramento das atividades agrícolas, em busca de um equilíbrio constante entre os elos.

Desta forma, nota-se a importância do questionamento dentro do processo investigativo. As respostas obtidas através destes métodos são de suma importância, pois, muitas vezes, acabam por derivar elucidações significativas para as demandas existentes.

Portanto, a presente obra traz em sua composição pesquisas inovadoras com o intuito de difundir ideias relevantes para o cenário agrícola mundial, com informações de considerável valor para leitores, no que se refere a inovações tecnológicas e outros assuntos.

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SUMÁRIO

CAPÍTULO 9

EFFICIENCY EVALUATION OF DIFFERENT COAGULANT AGENTS ASSOCIATED WITH A DIRECT FILTRATION SYSTEM IN WATER TREATMENT

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ABSTRACT: Developing studies for water treatment that seek to adapt and balance the preservation of the environment is fundamental for the present time, which is why studies with organic coagulants have become so important. Aluminum sulfate is widely used, but high concentrations can cause problems to human health. The tests for water treatment were carried out simulating the processes that occur in a water treatment plant, such as coagulation, flocculation, sedimentation, and filtration. The parameters pH, electrical conductivity, and turbidity were analyzed. The coagulants Tannin, Aluminum Sulfate, *Moringa Oleifera,* Ferric Chloride, Bufloc 5122 and, Bufloc 5122 accompanied by the auxiliary Bufloc 5158 were used. The results showed that the coagulant extracted from the seed of *Moringa oleifera* stood out after direct filtration, showing results similar to ferric chloride, both showing results higher than 99% of turbidity removal. For pH, the results showed no variation, as for conductivity, *Moringa oleifera* presented values above the average due to its saline composition. It is concluded, therefore, that there is a possibility that an organic coagulant presents efficiency equivalent to an inorganic coagulant in water treatment, bringing benefits to the environment as it is a less polluting component.
KEYWORDS: Coagulants, filtration, water treatment.

AVALIAÇÃO DA EFICIÊNCIA DE DIFERENTES AGENTES COAGULANTES ASSOCIADO A SISTEMA DE FILTRAÇÃO DIRETA NO TRATAMENTO DE ÁGUA

RESUMO: Desenvolver estudos para tratamento de água que procurem adequar e equilibrar a preservação do meio ambiente é fundamental para os tempos atuais, por isso estudos com coagulantes orgânicos tornam-se tão importantes. O sulfato de alumínio é bastante

empregado, porém elevadas concentrações podem causar problemas à saúde humana. Os ensaios para tratamento de água foram realizados simulando os processos que ocorrem numa estação de tratamento de água, como a coagulação, floculação, sedimentação e filtração e foram analisados os parâmetros pH, condutividade elétrica e turbidez. Foram empregados os coagulantes Tanino, o Sulfato de Alumínio, a Moringa Oleifera, o Cloreto Férrico, o Bufloc 5122 e o Bufloc 5122 acompanhado do auxiliar Bufloc 5158. Os resultados mostraram que o coagulante extraído da semente de Moringa oleifera se destacou após a filtração direta, apresentando resultados semelhantes ao cloreto férrico, ambos apresentando resultados superiores a 99% de remoção de turbidez. Para o pH, os resultados não demonstraram variação e para a condutividade a Moringa oleifera apresentou valores acima da média devido sua composição salina. Conclui-se, portanto, que há possibilidade de um coagulante orgânico apresentar eficiência equivalente a um coagulante inorgânico no tratamento de água, trazendo benefícios ao meio ambiente por ser um componente menos poluente.
PALAVRAS-CHAVE: Coagulantes, filtração, tratamento de água.

1 | INTRODUCTION

Brazil has 12% of the world’s availability of freshwater. Even so, 80% of Brazilian water resources are found in the Amazon region, where the smallest part of the population lives and the water demand is lower (AGÊNCIA NACIONAL DE ÁGUAS, 2018), such outcome is a consequence of the great social and regional inequality present in the region. country (MACHADO, 2003). Therefore, developing new technologies and research in the area of water treatment that seeks to facilitate access to treated water is essential for the development of a disease-free society with quality of life.

According to Seckler (2017), the water treatment process can be considered as a set of water manipulations in its most different presentations, so that it can be classified as suitable for public supply. The processes are divided into coagulation (the stage in which suspended particles are agglomerated with the aid of a coagulant); flocculation (agglutination of smaller flakes of dirt into larger flakes); decantation (deposition of flocs by gravitational action) and filtration (the stage in which impurities are retained in a filter).

For Libânio (2010) filtration consists of a process capable of correcting failures that occurred in coagulation, flocculation, and sedimentation, ergo, filtration is responsible for retaining the colloidal particles of the water, thus improving the treatment and guaranteeing the quality of the water treated.

Currently, the most used inorganic coagulant for water treatment is aluminum sulfate ($Al_2(SO_4)_3$), but high concentrations of aluminum in the environment can be a cause of problems to human health (ROSALINO, 2011). Therefore, the use of organic coagulants based on seeds and tree bark has been a viable solution, as they have low toxicity and greater sustainability (SANTOS, 2011).

With this in mind, this study aims to approach water treatment in the sustainable concept of using organic coagulants as a way of replacing or aiding the use of inorganic coagulants in the process involved.

2 | MATERIAL AND METHODS

The tests were carried out at the UTFPR Water Resources Laboratory – Londrina campus. 12 L of synthetic water based on a kaolinite solution ($Al_2Si_2O_5(OH)_4$) were prepared to simulate turbidity levels close to 100 uT using the methodology of Mendes (1989). The research included six treatments using different coagulants, namely Tannin (T1), Aluminum Sulfate (T2), *Moringa Oleifera* (T3), Ferric Chloride (T4), Bufloc 5122 (T5), and Bufloc 5122 accompanied by auxiliary Bufloc 5158 (T6). A preliminary assay was carried out in which several concentrations of coagulants were randomly tested and it was defined that the most efficient concentration for T1, T2, and T4 was 6 mL L^{-1}, for T3 and T5 a concentration of 2 mL L^{-1} was used. 1 and 4 mL L^{-1} respectively. For the T6 treatment, the concentration of 3 mL L^{-1} was adopted.

To prepare the coagulant solutions, the following procedures were performed: for the coagulant extraction solution based on *Moringa Oleifera* seed, 10 g of the seed was crushed and diluted with 1 M NaCl in 1 L of distilled water. The solution was processed in a blender, and then the mixture was strained through a cloth sieve to remove the coarser organic matter, leaving only the coagulant liquid. Aluminum Sulfate, Ferric Chloride, and Bufloc 5122 coagulants were prepared by dissolving 1 g of the coagulant in 1 L of distilled water. Tannin and Bufloc 5158 were prepared by diluting 1 mL of each coagulant in 1 L of distilled water, and for Bufloc 5158 it was necessary to heat the water so that its complete dissolution was possible.

In the Jar-test equipment, the experiment was executed in duplicate and after adding the coagulants in their respective concentrations, the equipment was activated and the coagulation process was carried out for 3 minutes at 150 rpm, then reducing the rotation to 15 rpm. for 10 minutes in order to start the flocculation process, then turn off the device to characterize the sedimentation process (adapted from THEODORO (2012)).

For the construction of the filter, pre-tests were carried out where 3 filters were tested aiming to choose the best one for the development of this work and so the chosen filter was produced with sand with a granulometry from 0 to 0.425 mm (G1) in which it was filled 15 centimeters of the filter composing the top layer and a base layer of nonwoven geotextile.

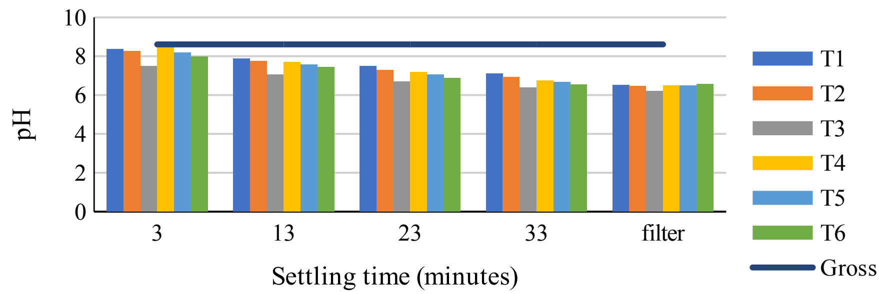
The analyzes during the sedimentation process were performed at an interval of 10 in 10 minutes, with the first collection being performed with 3 minutes of sedimentation and the last with 33 minutes. After collections, the pre-treated water from the jars was directed to the filters and after the passage of the water, the samples were collected for the last analysis.

The parameters analyzed were pH, electrical conductivity, and turbidity, all of which were analyzed by the methodology of APHA (2012).

3 | RESULTS AND DISCUSSION

Initially, the parameters observed for water in its raw state were pH 8.6; electrical conductivity 89.55 μS cm^{-1} and turbidity 107.5 uT, and Total Dissolved Solids 43 ppm.

Figure 1 shows the behavior of pH during the test.



Note: T1: tannin; T2: aluminum sulfate; T3: *Moringa oleifera*; T4: ferric chloride; T5: Bufloc 5122; T6: Bufloc 5122 and Bufloc 5158.

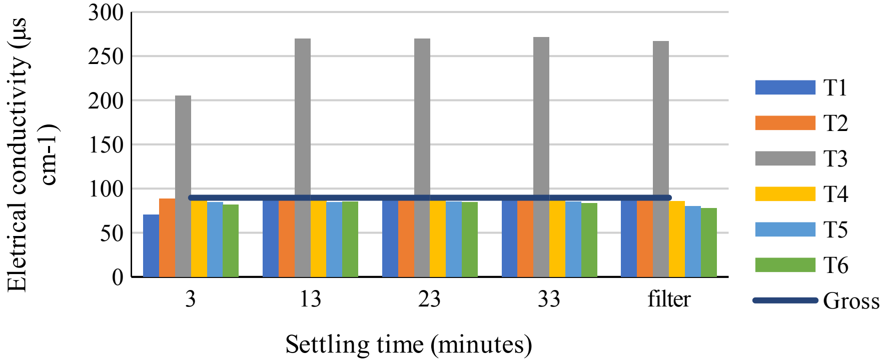
Figure 1 – Graph of pH behavior during the test.

Source: Own Authorship (2021).

When analyzing Figure 1, it is observed that the pH values fell as time progressed, remaining after filtration with values lower than the initial gross value of 8.6, a behavior corresponding to that presented by Borges and Pereira (2020) in their studies. Notably, of all treatments, treatment T3 had the lowest pH values, resulting in a pH value of 6.2 at the end of the test. It is worth mentioning that at the end of the experiment, during the passage through the filter medium, the T6 treatment showed the highest pH compared to the other treatments, showing values of 6.5. Despite this, the results showed that all treatments did not show great pH variation between them at the end of the test.

Figure 2 shows the values obtained from the variation of electrical conductivity during the experiment. Observing the results, it can be seen that the T3 treatment presented, taking into account the gross value of 89.55 μS cm^{-1}, high levels of electrical conductivity throughout the experiment, which was also observed by Borges and Pereira (2020).

It is noted that at 23 minutes the treatment reached its maximum peak when reaching values of 269.8 μS cm^{-1} and this uneven change to the other treatments is due to the fact that the coagulant based on *Moringa oleifera* seed extraction has the presence of NaCl in its composition, and once the salt releases Na^{+} ions into the solution, there is a considerable increase in electrical conductivity, as also pointed out by the study by Vizibelli et al. (2019).

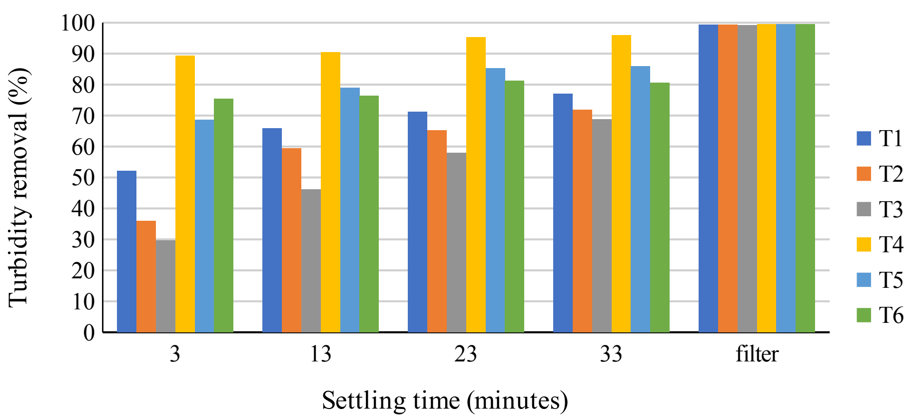


Note: T1: tannin; T2: aluminum sulfate; T3: *Moringa oleifera*; T4: ferric chloride; T5: Bufloc 5122; T6: Bufloc 5122 and Bufloc 5158.

Figure 2 – Graph of the electrical conductivity of values obtained during the test.

Source: Own Authorship (2021).

The electrical conductivity of the other treatments shown in Fig. 2 showed no significant differences in the gross water value, however, it is noticeable that in the T1 treatment there was an increase in the value obtained in the first analysis at 3 minutes of 70.3 μS cm^{-1}, with a value of 87 μS cm^{-1} at the end of filtration. Current Brazilian legislation does not present limit values for electrical conductivity. Figure 3 represents the turbidity removal efficiency results during the experiment.



Note: T1: tannin; T2: aluminum sulfate; T3: *Moringa oleifera*; T4: ferric chloride; T5: Bufloc 5122; T6: Bufloc 5122 and Bufloc 5158.

Figure 3 – Percentage of turbidity removal efficiency during the test.

Source: Own Authorship (2021).

As can be seen in Fig. 3, the T3 treatment showed low turbidity removal efficiency during the first and second collections and this was due to the large amount of organic matter from *Moringa oleifera*. The T3 treatment only obtained considerable result with time, at 43 minutes, and the same treatment showed an advance in the turbidity removal during the course of the sedimentation test, presenting values greater than 68%.

It is also observed that at the end of the passage of water through the filter medium, the turbidity removal efficiency of this same treatment presented values above 99%, thus emphasizing the filter's ability to retain the high amount of organic matter present in this organic coagulant.

Arantes et al. (2015) verified in their studies, using *Moringa oleifera* associated with slow filtration, removal of up to 95% for turbidity, corroborating these results.

The T4 treatment had a rapid effect, from the first 3 minutes, where it is possible to identify in Fig. 3 that the turbidity removal efficiency value reached the mark of 89%, and this value increased during the other collections. At 43 minutes, the T4 treatment reached 96% of turbidity removal, surpassing the other treatments. Higashi et al. (2016) point out in their study turbidity removal of up to 96%, using ferric chloride in water treatment.

Note that at the end of the test, all coagulants showed values greater than 99%, caused by the filter's ability to retain colloidal particles. Prado et al. (2007) observed in their studies using aluminum sulfate in water treatment turbidity removal efficiency higher than 80%. Demonstrating the possibility of using organic coagulants in water treatment, since they presented values equal to or more expressive than inorganic coagulants.

When the ANOVA analysis of variance, Table 1, is applied, it is observed that there is a significant variation in turbidity removal, both between treatments and over time, as both sources of variation have a P-value of less than 5% of significance, and F distribution value above the values delimiting the acceptance and rejection areas given by F critical.

Source of Variation	*SQ*	*gl*	*MQ*	*F*	*P value*	*F crit*
Time	5460,899	4	1365,225	17,87069	2,19822E-06	2,866081
Treatment	3876,208	5	775,2417	10,14786	5,93117E-05	2,71089
Error	1527,893	20	76,39463			
Total	10865	29				

Table 1. ANOVA analysis of variance to double factor without repetion.

Source: Own Authorship (2021).

Thus, the hypothesis that at least one of the sources of variation is statistically different from the others is validated. However, in order to determine the level of influence of the sources of variation, a greater volume of sample data would be necessary, a recommendation for future work.

4 I CONCLUSIONS

After the filtration process, it was possible to observe that the organic coagulant extracted from the *Moringa oleifera* seed stood out together with the ferric chloride since both presented results above 99% of turbidity removal. It was also observed that associating the coagulant made from the extraction of the *Moringa oleifera* seed to the water treatment with filtration was essential for an increase to 99% of turbidity removal efficiency. It is also noted that the T5 treatment showed better values than T6, evidencing the no need for the Bufloc 5158 auxiliary in the treatment of the water in question.

The results for the pH parameter did not show great inequalities to the gross value, showing that there is no need for correction on the water treatment. The electrical conductivity values did not show a great difference from the gross value, except for the use of *Moringa oleifera* seed, which is due to its saline solution in its composition, showed values much higher than the others.

Therefore, it demonstrated the possibility of an organic coagulant presenting equivalent or associative efficiency to an inorganic coagulant in the treatment of water in a system with filtration, being able, in this way, to bring benefits to the environment for being a less polluting component and being able to present greater sustainability to the process.

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